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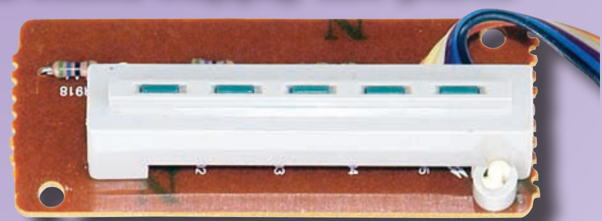

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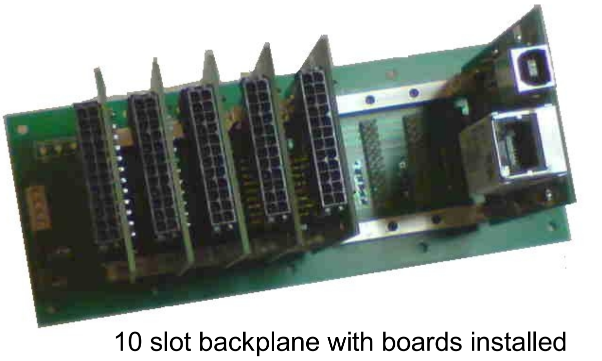

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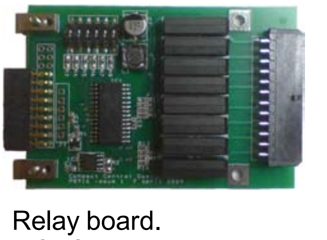

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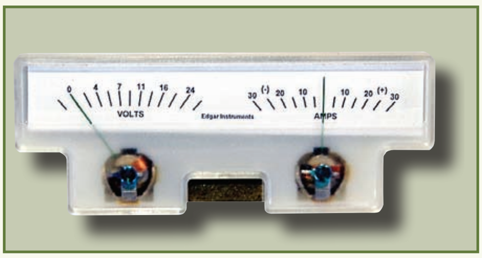

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Our February 2010 issue will be published on Thursday 14 January 2010, see page 80 for details.

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VOL. 39 No. 1 JANUARY 2010

A difficult year...

Another year has flown by, and like many of you I find myself reviewing the old year and starting to think about the new one. In 2009 – even with a recession – there was much to be excited about in technology. The pace of progress in electronics seems to have barely stopped for breath, and from smart phones to super computers, speed, storage and applications continue to grow in breath and depth.

For those of you who have had a tough time this year, I do hope 2010 brings you some of the fruits of a long-promised recovery. We have even heard politicians talk about a return to an economy where engineering plays more of a role, and I'm sure we would all welcome that. I for one have never lost faith in the inventiveness of Britain. I was even asked recently by a friend which branch of engineering I would recommend for his daughter – it would be a most encouraging sign if more school leavers were to return to the exciting professions of understanding, designing and making things.

Last, but not least, from myself, our publisher Mike Kenward and the hard-working EPE team and regular contributors, we wish all our readers a very happy Christmas and a successful new year. 2009 produced 12 excellent issues, filled to the brim with fantastic features, projects and news. We have the same range and quality planned for 2010 – and look forward to receiving feedback, email, letters and circuit ideas from our loyal readership. So, whether you enjoy a monthly trip to the newsagent, get your copy in the post, or you read EPE online, you can expect us to provide you with the very best hobby electronics magazine available in 2010.

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PROJECTS AND CIRCUITS
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A number of projects and circuits published in *EPE* employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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NEWS

A roundup of the latest Everyday News from the world of electronics

Blu-ray and 3D By Barry Fox

"EUROPE is a year behind the USA in getting the Blu-ray message across" admitted Yves Caillaud, from Warner studios and chairman of the Digital Entertainment Group in Europe. "It's taken longer than expected. One reason is that we have not been doing enough in-store demos." Caillaud was speaking at the Futuresource Entertainment Retailing and Supply Chain Conference in London recently.

Lindsay Brown, managing director, Operations, International, Eagle Rock Entertainment admitted: "There's been a lot of confusion – we have not been getting the back compatibility message across. People don't realise that a BD player will play their DVDs and CDs. People are reticent about buying a new machine and throwing away their old collection."

Earlier there had been enthusiastic talk about the new standard for 3D Blu-ray, due to be completed by the end of this year, so that 3D discs, 3D players and 3D TVs can be launched next year.

So, was Caillaud not concerned that all the talk about 3D, and the need for a new 3D player and 3D TV, might slow BD sales by encouraging consumers to wait for the something better that they now know is coming soon?

Said Caillaud: "We need to find the right balance, keeping people interested with new products, but not deterring them from buying. That's the way the PC industry works and consumers are accustomed to that.

"We need to avoid hesitation and get the message across that if you want to get the best out of your HDTV, you can get it now with Blu-ray. You have spent hundreds of pounds on a screen and are not getting the best out of it. We need to communicate a sense of urgency. Get it now."

So expect to see a strong push on 2D Blu-ray players this winter, ahead of the arrival of 3D Blu-ray next year.

FIVE YEAR WARRANTY

PICO TECHNOLOGY, the leading PC oscilloscope and data logger manufacturer, now cover their most popular products with a five-year warranty against manufacturing defects.

"Many companies offer just a one or two-year warranty," explained managing director Alan Tong. "We are so confident in the quality of our products that we have decided to give away a valuable extra guarantee, at no additional cost to the customer."

The new five-year warranty covers 15 USB oscilloscope models and five USB data loggers. All of the oscilloscopes and data loggers are PC-based, which means that they work in conjunction with the PC or laptop on your workbench. Because the products don't have a computer inside, Pico can put all of their design effort into the specialised instrumentation and software that you need to make accurate measurements. This also makes the products much smaller, lighter, less power-hungry and more economical than their bench-top counterparts.

Pico have just announced the availability of the PicoScope 6000 series oscilloscopes. The first USB scopes to offer a 5GS/s real-time sampling rate. This is accompanied by an impressive 350MHz bandwidth on all four channels. The scopes also have a huge one-gigasample memory buffer, unsurpassed on any bench-top or USB scope.

The PicoScope 6000 Series is the latest product of Pico Technology's 18 years of experience in PC oscilloscope design. The instruments pack more performance and features than ever before into a space-saving USB oscilloscope enclosure. As well as the headline specifications, the scopes offer a built-in function generator, arbitrary waveform generator, mask limit testing, switchable bandwidth limiting on each channel, and switchable 1MΩ and 50Ω inputs. This is in addition to the spectrum analysis, advanced triggering and serial decoding that are already standard features of Pico USB oscilloscopes

The PicoScope 6000 Series oscilloscopes are on sale now, priced at £3000 for the 32-megasample model and £4000 for the 1-gigasample model. Kits with probes are priced at £3500 and £4500 respectively.

With the added reassurance of the new five-year warranty, Pico believe their oscilloscopes and data loggers now offer unbeatable value for money. Visit their website at **www.picotech.com** to download datasheets, find your local distributor or order online.

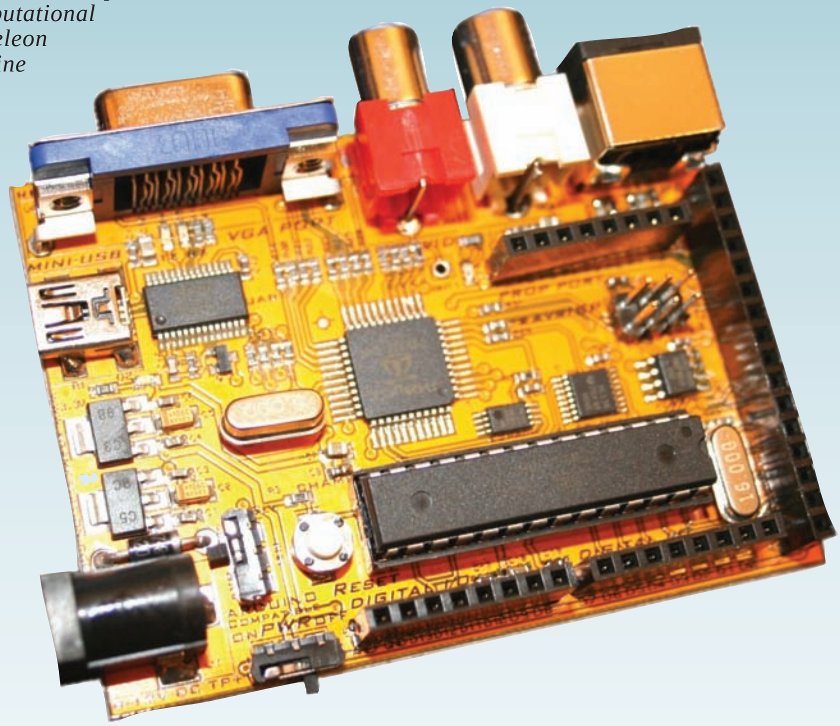
CHAMELEON AVR AND PIC

The Chameleon is the evolution of the high performance, small footprint, application development board. Similar to the BASIC Stamp and Arduino in concept, the Chameleon takes these products to the next level with a huge leap in computational performance as well as I/O interfaces. Simply put, the Chameleon is a credit-card-sized computer with two processors, nine processing cores, 1MByte of on board Flash, 64K of EEPROM, and over 180MIPS of processing power! If that wasn't enough, the numerous I/O interfaces include composite video for NTSC/PAL generation, VGA, audio out, PS/2 for keyboards and mice. Additionally, the Chameleon has a number of digital I/Os and analogue inputs, making it perfect for industrial controllers, experimentation, education, wearable computing, or hobbyist use.

The real power of the Chameleon is based on its dual processor design. The Chameleon comes in two flavours; the AVR 8-bit and PIC 16-bit versions. The AVR version uses the Atmel AVR328P 8-bit processor, while the PIC versions uses the Microchip PIC24 16-bit as the main master processor (client) along with the Parallax multicore Propeller chip as the media processor (server).

Thus, the AVR/PIC programming is very easy, and with simple APIs you can develop very complex and rich media applications that leverage the incredibly powerful Propeller chip's media rendering abilities and huge software library. For example, you can generate TV signals, VGA, or read keyboards and mice with a few lines of code.

The Chameleon is both a complete AVR/PIC application development board, and a Propeller development board. Both processors can be independently programmed and used. Additionally, the AVR/PIC and Propeller both have their own digital I/Os, so theoretically you can run two applications on the Chameleon and use it that way, or use the processors together over the SPI link.



You can choose from C/C++, Assembly Language or BASIC to program the Chameleon. Last, but not least, the Chameleon has a break-away experimentation protoboard built into the PCB. You can solder directly onto it, or place the mini solderless breadboard that comes with the Chameleon onto the area. If you don't want the experimenter board, you simply break it away and snap it off.

Visit **www.xgamestation.com** *for full details.*

See, Hear, Speak,Touch

THE new ASUS videophone touch Aiguru SVIT provides unlimited free calls through the Skype interface. It sports a range of easy-to-use features, including a 180mm high quality touchscreen display, fun and colourful icon-driven interface and integrated wi-fi support.

"Skype goes beyond traditional voice calling and brings people closer through rich, real-time video communication," said Manrique Brenes, Skype's director of business development and product management for consumer electronics. "The device's touchscreen makes video calling an even easier and more accessible way for people to communicate. It offers the benefits of Skype video calling and exceptional audio quality – allowing friends, families, and small businesses to share their worlds face-to-face, without being tied to a computer."

This is the world's first videophone to feature a large high-resolution phone touch-enabled screen. Effortless fingertip control, combined with a clear and highly visible display makes it a breeze to highlight selections and enter characters on screen, and adds a fun and user-friendly dimension to video calling.

The videophone also presents users with a colourful and simple icon interface, which takes the headache out of Internet calling and instead presents users with a fast and easy way to make and receive Skype-to-Skype video and voice calls, without the need for computing knowledge.

The videophone does not require a computer or any additional software to get connected. Users can quickly and simply be ready to make video calls in just three easy steps: connect to a broadband connection (wireless or cabled); create a new Skype account or sign into an existing one; start video calling your contacts. The ASUS Videophone Touch AiGuru SV1T is available now at an SRP of £199 inc. VAT. Visit **www.asus.co.uk** for more details.

Remote-Controlled Mains Switch

Want to switch mains appliances on and off remotely? This UHF Remote Mains Switch can do it for you. It's operated using a handheld UHF transmitter, and an in-built timer also enables the unit to turn off automatically after a preset period.

By JOHN CLARKE

THERE are many instances when it would be convenient to switch an appliance on or off remotely, rather than switching it manually. Such circumstances include switching on pathway lights when you arrive home, switching garden and/or pool lighting on or off, and switching power to water pumps. Remote switching can also be very convenient for appliances that are difficult to access, eg, in a factory.

This unit was originally designed to switch mains-powered water pumps on and off in response to signals transmitted by a water tank level meter base station. However, we soon realised that by adding a separate handheld transmitter to control the unit, it could also be used as a stand-alone unit for lots of other applications.

Commercial remote control mains-operated switches are readily available for switching appliances rated up to about 1000W. However, if you want to switch devices rated over 1000W, or control water pumps, then you need the UHF Remote Mains Switch described here. It can switch devices rated at up to 2500W over a range of up to 200m. That's 10 times the range typically available from the low-cost commercial units!

Main features

As previously indicated, the UHF Remote Mains Switch is controlled using a handheld UHF transmitter. The latter has just two switches for power control, one to switch the appliance on and the other to switch it off. An indicator LED located just above the 'On' switch lights briefly during each UHF transmission, to indicate that the signal has been sent.

A feature of the transmitter unit is that is can be set to one of 10 identities ('codes'). This means that you can independently control up to 10 UHF Remote Mains Switches using a single transmitter.

Let's say, for example, that you have two UHF Remote Mains Switches. In this case, one of these can be set as identity '1', and the other as identity '2'. The UHF transmitter can then be set to control either unit by selecting the required transmitter identity number.

In other words, when the transmitter is set to identity '1', it will control the first Mains Switch with identity '1'. Similarly, when set to identity '2', it will control the unit with identity '2'.

Note that a small screwdriver is required to change the transmitter's identity. It's just a matter of changing the setting of a BCD switch via an access hole in the front panel (below the 'Off' button).

Similarly, a Water Tank Level Meter Base Station (to be published in a future issue) transmits the identity of the pump that's to be controlled. This pump is then switched by the UHF Remote Mains Switch that's set to the same identity. Note that you will require a separate UHF Remote Mains Switch for each pump you wish to control.

Encode switch

The transmission range is such that you can easily control a UHF Remote Mains Switch up to 200m away. This means that, in a suburban environment, you could easily end up controlling a neighbour's UHF Remote Mains Switch – or vice versa – unless special precautions are taken.

In this unit, a 16-position encode switch is included to prevent this from happening. Basically, the encode

The UHF Remote Mains Switch can switch loads of up to 1875W or 2500W – see text.

setting on the UHF Remote Mains Switch must match the encode setting on the UHF transmitter before it will operate in response to the UHF signal. This means that if both you and a neighbour have UHF Remote Mains Switches set to identity 1, you can simply select a different encode value to prevent false triggering.

Timer

An inbuilt timer in the UHF Remote Mains Switch allows you set the unit to automatically turn off after a preset period. This period is set by another BCD switch (S3) during construction, and ranges from one minute through to four hours in 15 steps. Table 1 shows the full range of periods available.

This automatic switch-off feature is useful if you are controlling pathway or garden lights. For example, you might want the unit to automatically switch the pathway lights off after a few minutes, or switch the garden lights off after a couple of hours.

Alternatively, the unit can be set to remain on permanently, or until an 'off' signal is received from the transmitter (ie, either from the hand-held transmitter or from a base station pump transmitter).

Brownout protection

Another feature of the UHF Remote Mains Switch is 'brownout' detection, with automatic switch-off should a brownout occur.

Brownouts occur when the mains voltage drops to a lower than normal level, usually because of a fault in the supply. The lowered voltage not only dims house lights, but can also cause motors to overheat and burn out.

Basically, burn-out occurs because the current through a motor's induction windings increases when it is not spinning at its correct speed (ie, when the supply voltage is low). In fact, in severe brownouts, the voltage can be so low that the motor will not turn at all. In that situation, the motor will quickly overheat and suffer permanent damage.

By including brownout detection, the motor is protected by switching off the power if the supply voltage falls below a preset value. Brownout detection is vital, for example, when it comes to preventing burn-out of mains-powered water pumps.

Presentation

As shown in the photos, the UHF Remote Mains Switch is housed in a plastic enclosure with a general purpose three-pin chassis-mount mains socket on the front panel. Also included on the front panel is a neon indicator to show when power is applied to the output socket, plus a pushbutton switch to manually switch the unit on and off.

Power indication for the unit itself is provided by a neon indicator within the mains switch (S5).

An internal relay is used to switch the mains power to the mains output socket (SK1). This relay is a high-current type that's suited to withstanding the high start-up currents associated with motors. A heavier duty relay can be used if required to power motors rated up to 2500W.

The transmitter is housed in a case measuring 135 × 70 × 24mm. It's powered by a 9V battery and sends out a coded 433MHz signal.

Circuit details

The full circuit diagram for the UHF Remote Mains Switch is shown in Fig.1. It's based on IC1, a PIC16F88-I/P microcontroller. This monitors

Main Features

- Switches loads of up to 1875W (or 2500W using 10A mains wiring)
- Up to 10 units can be used with the transmitter, each with a separate identity
- 16 encoder selections
- Over 200m range
- Unit is operated using a separate handheld UHF transmitter
- On and off switching via remote transmitter or local switch
- Timer operates from one minute to four hours in 15 ranges, plus a continuously on selection
- Brownout detection switching
- Optional power-on variation
- Not suitable for security or safety-critical applications.

the signals from a 433MHz receiver module and controls the mains output socket via a relay circuit accordingly.

In operation, the 433MHz receiver (RX) picks up the transmitter signal and applies the resulting data to IC1's RA5 (pin 4) input via a 1kΩ current-limiting resistor. This resistor is included because the RA5 input can cause IC1 to latch up if excessive current flows into or out of this pin. This could happen if the input goes above 5V or below the 0V supply rail.

Data signal

The data signal is read by IC1 by clocking it in at a rate set by the transmission locking pulse. It is then accepted by IC1 if the format is correct, but will be rejected if its identity and encode values do not match the settings of BCD (binary coded decimal) switches S1 and S2.

Switch S1 (Identity) is arranged as a rotary switch with 10 settings ranging from 0 to 9. It connects the RB0, RB1, RB2 and RB3 inputs of IC1 to 'ground' when its 2, 4, 1 and 8 switches are closed respectively.

Conversely, the RB0 to RB3 inputs are pulled to the +5V supply rail when their corresponding switches are open. That's because each input has an internal pull-up resistor of about 20kΩ. In operation, the switch settings for S1 can be read by IC1 because a low voltage on one of the inputs means that its corresponding switch is closed, while a high voltage means that the switch is open.

BCD switches S2 (Encode) and S3 (Timer) are monitored in a similar way. However, these have six extra positions labelled A to F, giving a total of 16 positions. Note that the RA0, RA1, RA6 and RA7 inputs of IC1 that monitor S3's setting are pulled to +5V via external 10kΩ resistors. These resistors are necessary because there are no internal pull-ups at the RA pins.

Switching the relay

IC1's output at RA3 (pin 2) controls relay-driver transistor Q1 via a 330Ω resistor. When RA3 is high, Q1 switches on and so relay RLY1 also turns on and switches mains power to the mains output socket (ie, it switches the 'Live' lead). Diode D5 clamps the back-EMF voltage that is produced when the relay coil switches off, to protect the transistor.

Pushswitch S4 is used to manually switch the relay on or off with each consecutive pressing. This switch connects to IC1's RA4 (pin 3) input and pulls this input to ground when closed. Conversely, a 1kΩ resistor pulls RA4 high when the switch is open. The 100nF capacitor bypasses any 'glitches' that may otherwise cause false switching.

Power supply

Power for the UHF Remote Mains Switch comes from the mains via transformer T1. The transformer's 12.6V secondary voltage is then full-wave rectified using diodes D1 to D4, and filtered using 470µF and 100µF electrolytic capacitors.

The resulting 17V DC rail is then applied to 3-terminal voltage regulators REG1 and REG2 to derive regulated +5V and +12V rails. The +5V rail is used to power IC1 and the 433MHz receiver module (RX), while the +12V rail powers the relay (RLY1).

Note that the outputs of REG1 and REG2 are each bypassed using 10µF capacitors. In addition, a 100µF capacitor and two 100nF capacitors are used to further decouple the supply for IC1 and the 433MHz receiver module.

Brownout

IC1's AN2 (pin 1) input is used for brownout detection. Basically, this input samples the 17V rail via a voltage divider consisting of a 22kΩ resistor and a 10kΩ trimpot (VR1). VR1's wiper (moving contact) voltage is filtered using a 10µF capacitor (to smooth out any 100Hz ripple and transients) and applied to the AN2 input via a 1kΩ resistor.

During the setting-up procedure, VR1 is adjusted so that the voltage at AN2 is +2.5V when the mains voltage is 250V AC. If a brownout subsequently occurs and the mains drops to below about 200V AC, the voltage applied to AN2 will fall below 2V. This is detected by microcontroller IC1, which then switches the relay off to disconnect mains power from the mains output socket.

The relay subsequently switches on again when the mains supply returns to normal.

Loading problems

One small problem with monitoring the 17V rail is that it varies with load. Relay RLY1 has a coil resistance of 160Ω, and so there is an extra 75mA drawn from the 17V rail when the relay is on. As a result, this supply rail drops in level when the relay is on, so we have to take this into consideration.

In practice, it's just a matter of ensuring that trimpot VR1 is set when the relay is on and power is being applied to the mains output socket. By doing this, the brownout detection operates correctly when the mains voltage drops to 200V AC.

Note also that we have included a 470Ω resistor across the 160Ω relay coil, and this reduces the effective resistance to 120Ω. We have done this

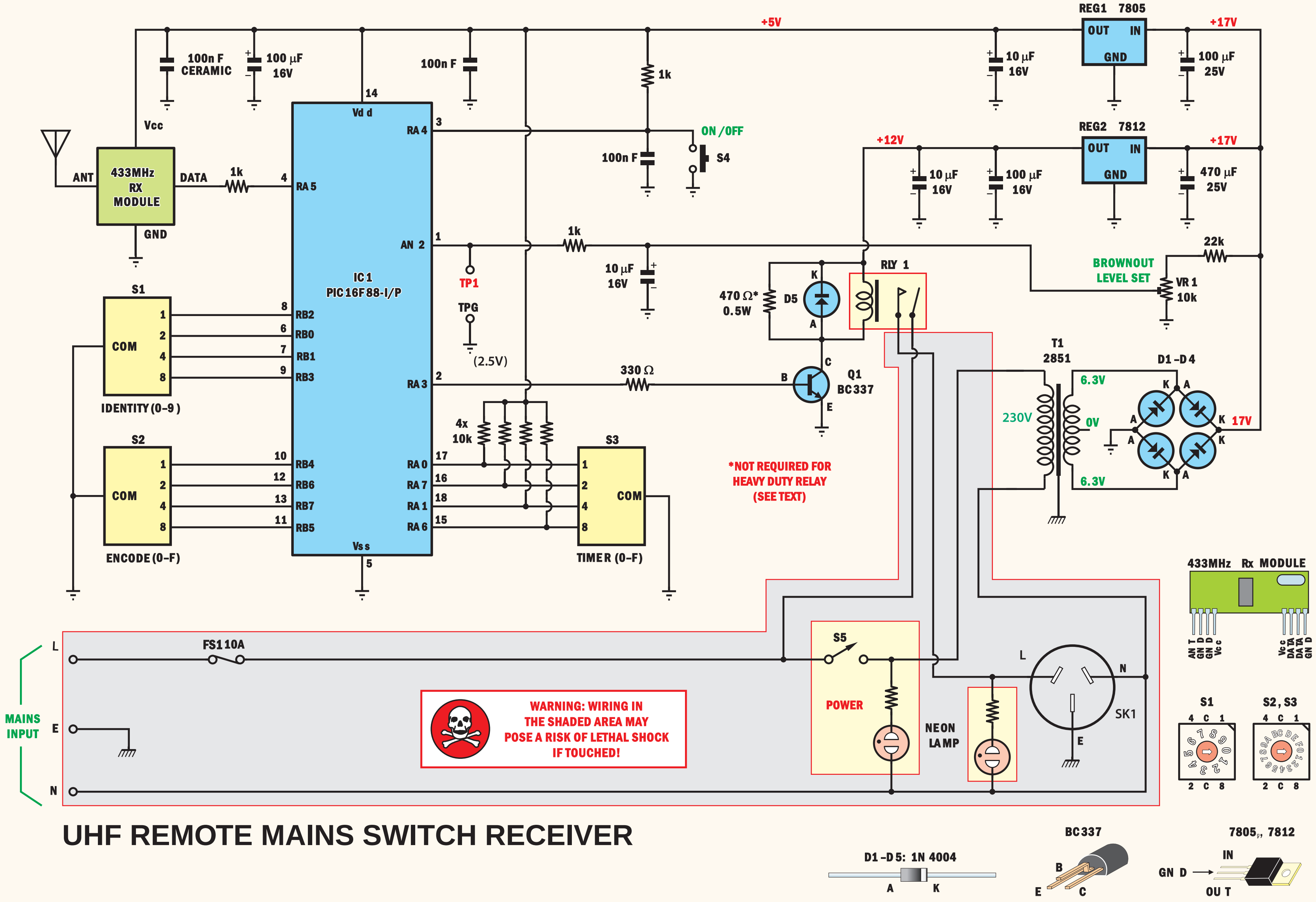


Fig.1: the circuit for the UHF Remote Mains Switch is based on a 433MHz receiver module and a PIC16F88-I/P microcontroller (IC1). The microcontroller processes the data from the receiver and controls relay RLY1, which switches the power to the mains socket (SK1) accordingly.

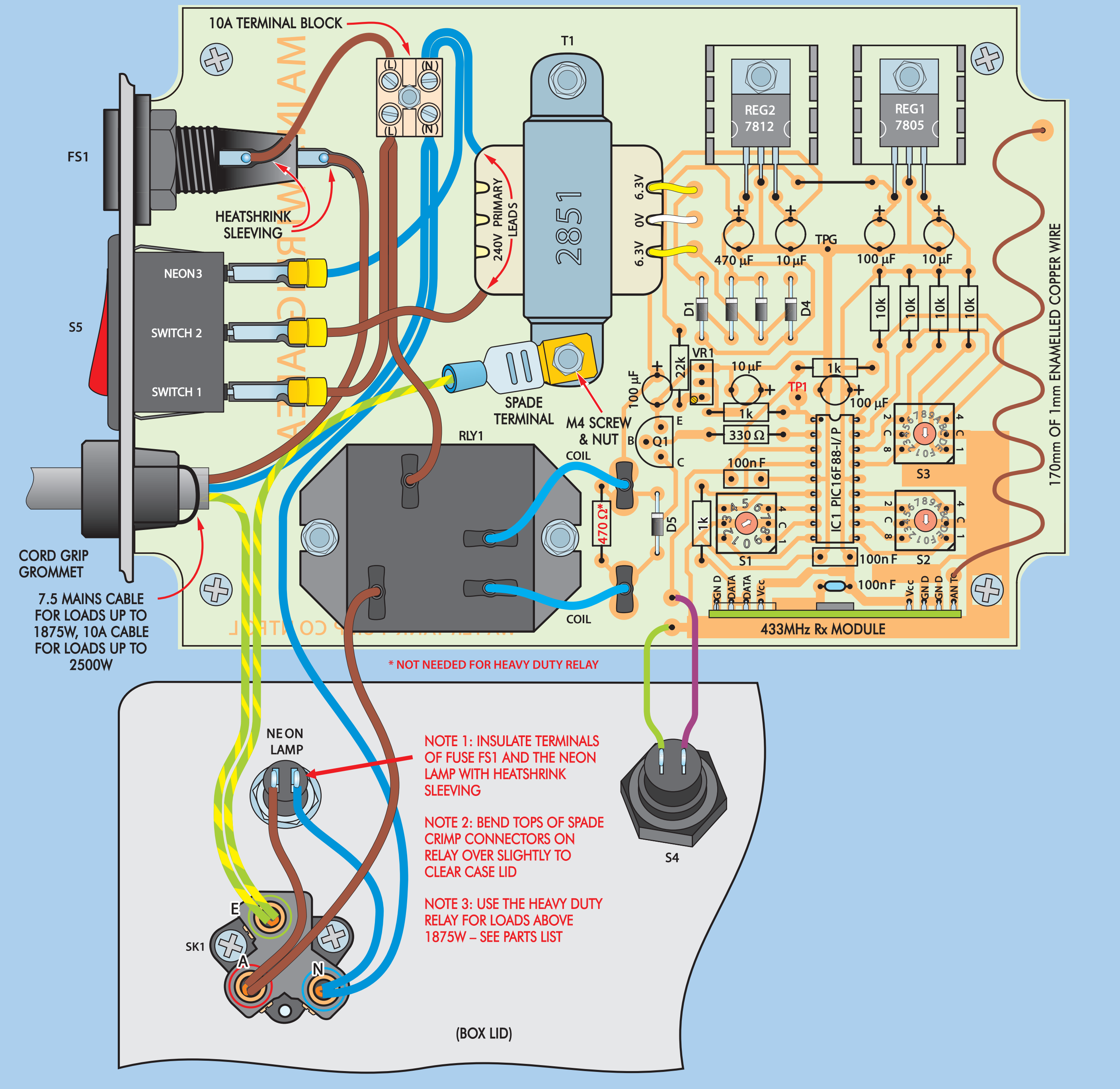


Fig.2: follow this parts layout and wiring diagram to build the UHF Remote Mains Switch. Note that all wiring must be run using 240V AC cable (see text) and this must be firmly secured using cable ties as shown in one of the photos.

so that a heavy-duty relay that has a coil resistance of 120Ω can be used instead, without affecting the brownout settings. The 470Ω resistor is not used with the 120Ω relay.

Another possible problem is that when the relay switches off due to a brownout, the 17V rail immediately rises again due to the reduced load. This could cause the relay to immediately switch on again, only to then switch off again when the 17V rail drops. This cycle could thus go on indefinitely, as the AN2 input repeatedly goes above and below 2V, thereby causing relay 'chatter'.

To circumvent this relay chatter, the microcontroller doesn't switch the relay back on again following a brownout until its AN2 input rises above 2.5V, corresponding to a mains voltage of 220V AC. When the relay is switched on, the voltage at AN2 will then fall to 2.2V, but this is still 200mV above the voltage required to switch off the relay and so the relay remains on.

Software

The software files will be available via the *EPE* Library site, accessed via **www.epemag.com**. Pre-programmed

PICs will also be available from Magenta Electronics – see their advert in this issue for contact details.

Construction

Construction of the UHF Remote Mains Switch is straightforward, with most of the parts installed on a PC board coded 738 and measuring 160mm × 110mm. This board is available from the *EPE PCB Service*.

The only off-board parts are the mains output socket (SK1), push-button switch S4, power switch S5, the neon lamp and the fuseholder. Fig.2 shows the interwiring and component layout on the PC board.

Begin construction by carefully checking your board for any defects, such as shorted or 'open-circuit' copper tracks. That done, check that the hole sizes are correct. In particular, the holes for the four corner mounting screws and for REG1 and REG2 must be 3mm in diameter, while the mounting holes for transformer T1 and the relay must be 4mm in diameter.

You should also check that the main PC board is cut and shaped to size so that it fits into the box. If not, you can make the corner cut-outs using a hacksaw and a round file.

Board assembly

Now for the board assembly. Install the resistors first, taking care to place each in its correct position. You should also use a DMM (digital multimeter) to double-check each resistor value before mounting it in position.

Note that if you are using the 120Ω heavy-duty relay, then the 470Ω resistor immediately to its right is not used – see Fig.2.

Once the resistors are in, install the wire link (it goes in between the two regulators), then install the PC solder stakes for the antenna connection at bottom right and for the 'test points' TP1 and TP GND. In addition, you will need to install another three PC stakes to terminate the transformer's secondary leads (6.3V, 0V, 6.3V), plus another two to terminate switch S4's leads.

Diodes D1 to D5 are next on the list. Make sure these are oriented correctly before soldering their leads. That done, install a socket for IC1, making sure its notched end matches the position shown on Fig.2. Do not install IC1 yet – that step comes later, after the power supply has been checked.

Next on the list are the capacitors. Be sure to orient the electrolytics as shown, and note that the 100nF ceramic capacitor goes in next to the 433MHz receiver module. The other two 100nF capacitors are MKT polyester types. One is just below one end of IC1, while the other is just above BCD switch S1.

Regulators REG1 and REG2 are both mounted horizontally on the PC board. The first step is to bend their leads down through 90° so that they will go through their PC board holes. In each case, the regulator's two outer leads are bent down 8mm from its body, while its centre lead is bent down 5mm from the body.

That done, secure each regulator together with a U-shaped heatsink to the PC board using an M3 × 10mm machine screw and nut. Be careful not to get the regulators mixed up – the 7805 (REG1) mounts on the right-hand side.

Tighten each assembly down firmly before soldering their leads and trimming them to length. Do not solder the regulator leads *before* tightening the mounting screws, as this could stress the soldered joints and fracture the board's copper tracks.

Next, install trimpot VR1, transistor Q1 and the three BCD switches. Be sure to use the correct BCD switch at each location (S1 is the 0-9 switch) and note that they must be oriented exactly as shown.

Receiver module

Follow these parts with the 433MHz receiver module, again taking care to ensure it goes in the right way around. The pin designations are all clearly labelled on the back of the module, and you can also match the orientation of the module against the photographs.

The antenna is made using a 170mm length of 1mm dia. enamelled copper wire. This is formed into a gentle spiral by winding it over a 10mm former (eg, a drill). As shown in Fig.2, it extends from the antenna PC stake to a hole in one corner of the PC board, immediately to the right of REG1.

Be sure to scrape away the enamel insulation from the wire ends before soldering it in position.

Note: for safety reasons, the antenna must be fully enclosed in the plastic case. Under no circumstances should it be mounted externally, nor should any part of the antenna protrude from the enclosure. The reason for this is that if a mains wire comes adrift inside the case, it may contact low-voltage circuitry and so the antenna may also become live (ie, at 230V AC) .

The next step is to install two PC-mount 6.4mm spade terminals immediately to the right of RLY1 (these are used to terminate the leads from the relay's coil). That done, the relay and transformer can both be secured in position using M4 screws, nuts and star washers.

Note the Earth lug that's fitted under one of the transformer mounting screws. Before fitting this, be certain to scrape away the enamel from the transformer mounting foot to ensure good contact.

You Need A Ratchet Type Crimping Tool

One essential item that's required to build this project is a ratchet-driven crimping tool, necessary for crimping the insulated quick-connect terminals to the leads.

The tool should feature double-jaws so that the bared wire end and the lead insulation are crimped in a single action.

Don't even think of using one of the cheap (non-ratchet) crimpers that are typically supplied in automotive crimp kits. They are not up to the job for a project like this, as the amount of pressure that's applied to the crimp connectors will vary all over the place. This will result in unreliable and unsafe connections at the mains switch and relay terminals.

By contrast, a ratchet-driven crimping tool applies a preset amount of pressure to ensure consistent, reliable connections.

If you don't have a suitable crimping tool, then it will be necessary to solder the leads to the mains switch and relay, and then cover their connections with heatshrink sleeving.

Parts List – Remote-Controlled Mains Switch

1 PC board, code 738, available from the *EPE PCB Service*, size 160mm × 110mm
1 IP65 ABS enclosure, size 171 × 121 × 55mm
1 433MHz UHF data receiver (RX) (Jaycar ZW-3102 or equiv.)
1 12.6V 2VA 150mA centre-tapped mains transformer (T1)
1 12V 160Ω coil relay with 20A 220V AC contacts. **Note**: for loads above 1875W, use a 30A relay
1 2-way 10A mains terminal block
1 0-9 BCD DIL PC-mount switch (S1)
2 0-F BCD DIL PC-mount switches (S2,S3)
1 momentary push-to-close 250V AC panel-mount mains switch (S4)
1 SPST mains rocker switch with neon indicator (S5)
1 panel-mount 240V AC neon indicator
1 250V AC 10A panel-mount safety fuseholder
1 10A fast-blow fuse (to suit fuseholder) (FS1)
1 7.5A mains cord and plug with earth (or 10A cord and plug for controlling appliances rated at up to 2500W)
1 13A mains flush-mounting panel socket (SK1)
2 20°C/W TO-220 mini finned heatsinks, 19 × 19 × 10mm
1 cordgrip grommet for 6.5mm OD mains cable
1 18-pin DIL IC socket
9 100mm cable ties
8 6.4mm fully-insulated spade crimp connectors for 1mm^2 wire
2 4.8mm fully-insulated spade crimp connectors for 1mm^2 wire
1 chassis-mount 6.4mm spade terminal
2 PC-mount 6.4mm spade terminals
4 M4 × 10mm screws
4 M4 nuts
4 M3 × 6mm screws
2 M3 × 10mm screws
1 M3 ×15mm screw
3 M3 nuts
1 200mm length of 7.5A blue mains wire (or 10A for up to 2500W)
1 200mm length of 7.5A brown mains wire (or 10A for up to 2500W)
1 100mm length of 10mm heatshrink tubing
1 50mm length of 4mm heatshrink tubing
1 170mm length of 1mm enamelled copper wire
1 25mm length of 0.8mm tinned copper wire
6 PC stakes

Semiconductors
1 PIC16F88-I/P microcontroller, programmed with 1010208A.hex (IC1)
1 7805 5V regulator (REG1)
1 7812 12V regulator (REG2)
1 BC337 *NPN* transistor (Q1)
5 1N4004 1A diodes (D1-D5)

Capacitors
1 470µF 25V PC electrolytic
1 100µF 25V PC electrolytic
2 100µF 16V PC electrolytic
3 10µF 16V PC electrolytic
1 100nF MKT polyester (code 104 or 100n)
1 100nF ceramic (code 104 or 100n)

Resistors (0.25W, 1% metal film)
1 22kΩ   1 470Ω 0.5W
4 10kΩ   1 330Ω
3 1kΩ
1 10kΩ top-adjust multiturn trimpot (code 103) (VR1)

The board assembly can now be completed by mounting the two-way 10A mains terminal block. Secure it using an M3 × 15mm screw, nut and lockwasher.

Final assembly

The UHF Remote Mains Switch is housed in an ABS enclosure measuring 171 × 121 × 55mm. If you buy a kit, then the box will probably be supplied pre-punched and with screened lettering on the front panel (or an adhesive label). If not, then you will have to drill the holes yourself.

Basically, you will have to drill and shape holes in one end of the case for the fuseholder, the mains switch and the cordgrip grommet. That done, you will have to drill holes in the lid for the mains output socket, the neon indicator and for pushbutton switch S4.

The large cutout for SK1 can be made by drilling a series of small holes around the inside perimeter, then knocking out the centre piece and filing the job to a smooth finish.

You will, of course, have to adapt this cutout according to the type of mains socket/plug you use – ie, Euro IEC320 connectors. Make sure the depth of the case can take any mains connector you use.

Once the drilling is completed, install the PC board, safety fuseholder and power switch and check where the two-way terminal block should be positioned. Mark and drill a mounting hole for this in the PC board, then secure it in position using an M3 ×15mm screw and nut. The PC board can then be secured inside the case using four M3 × 6mm screws.

Note that you must use the correct safety fuseholder, as specified in the parts list. Do not substitute for this part, as other fuseholders may pose a shock hazard.

Interwiring

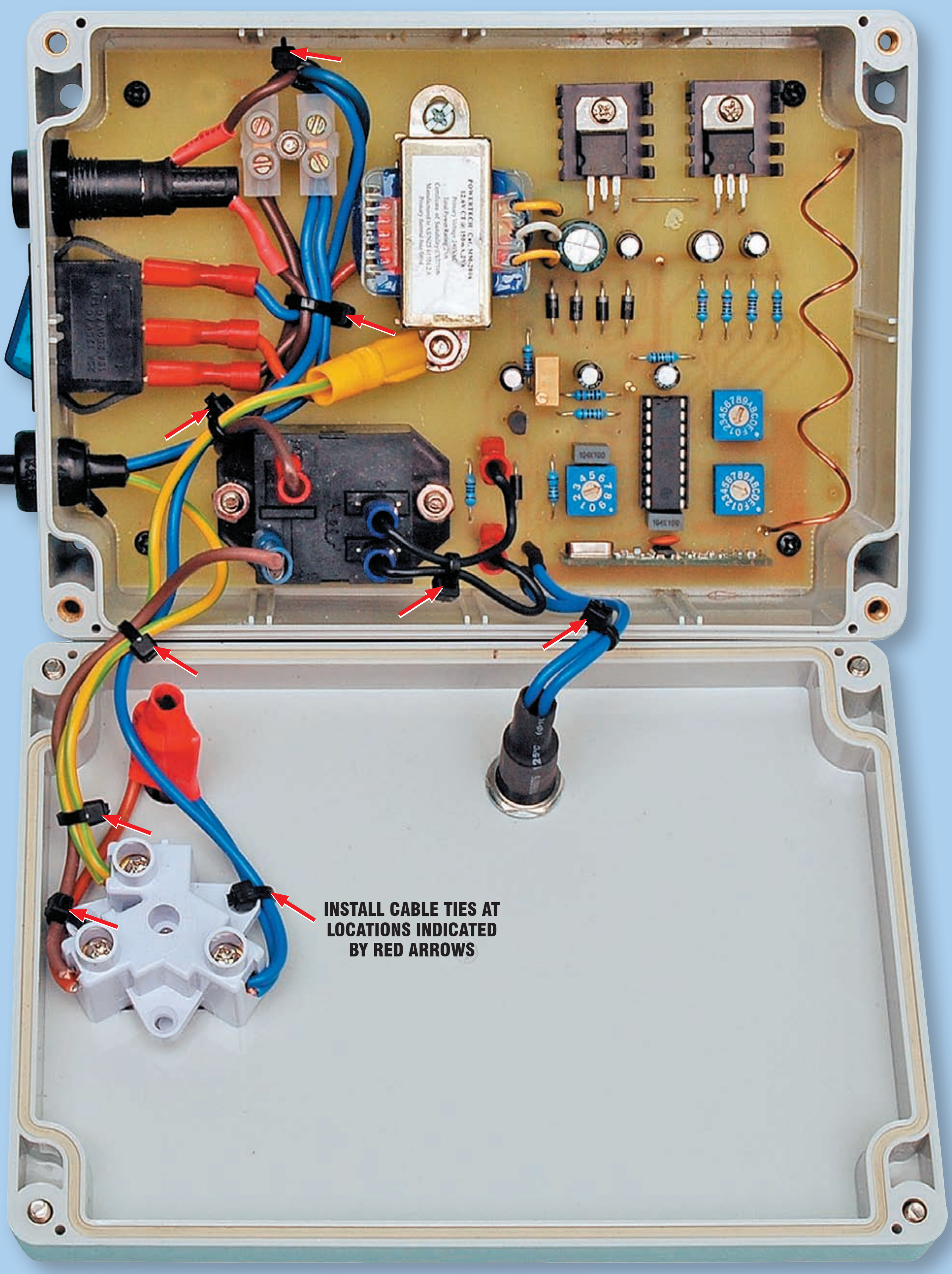
It's now simply a matter of completing the wiring, as shown in Fig.2. All wiring must be run using mains-rated cable. **You can use 7.5A cable throughout for powering appliances rated up to 1875W, but be sure to use 10A cable where indicated if you want to power appliances that are rated up to 2500W.**

Note that the brown cable is used for the Live wiring, while the blue cable is used for the Neutral leads. **The green/yellow-striped wire is used for the earth wiring only, and the Earth lead from the mains cord must go straight to the output socket – SK1.**

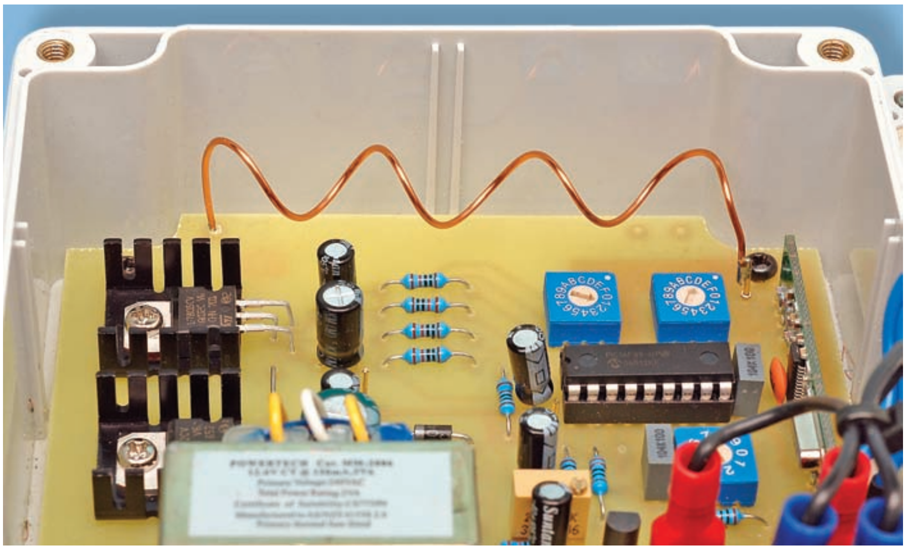
Crimp connectors

The connections to the mains switch (S5) and the relay are all made via insulated spade crimp connectors. **Be sure to use fully-insulated connectors here, as these terminals all operate at 230V AC.**

A proper ratchet-driven crimp tool (see panel) is an absolute necessity to attach the connectors to the leads. Low-cost automotive type crimpers are



This is the view inside the completed UHF Remote Mains Switch. Be sure to use fully insulated spade connectors for the connections to the mains switch and the relay, and insulate all other connections with heatshrink sleeving to ensure safety. The wiring must be secured using cable ties at the positions indicated by the red arrows.



This close-up view shows how the antenna is mounted at one end of the PC board. It's made by winding a 170mm length of 1mm enamelled copper wire onto a 10mm mandril (eg, a drill).

definitely not suitable here, as their use would result in unreliable and unsafe connections.

The leads to the fuseholder (FS1) and neon lamp are soldered to their respective terminals. Note that the Live lead from the mains cord goes to the terminal on the end of the fuseholder. Note also that *all* these connections *must* be insulated with heatshrink sleeving – see photos.

Similarly, use heatshrink sleeving to insulate switch S4's terminals.

The transformer secondary leads and the leads from switch S4 connect to adjacent PC solder stakes. Once again, these connections should all be insulated with heatshrink sleeving to ensure reliability.

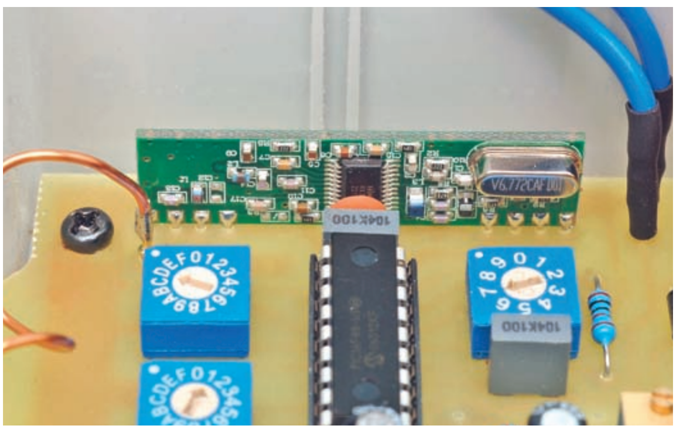
Take great care when making the connections to the mains output socket (SK1). In particular, be sure to run the leads to their correct terminals (this is usually clearly labelled) and do the screws up nice and tight so that the leads are held securely. Similarly, make sure that the leads to the mains terminal block are also firmly secured.

Once the wiring is complete, it should be secured using cable ties. This is done so that if a mains wire does come loose, it cannot move and make contact with any low-voltage components on the PC board.

One of the photographs clearly shows the locations of the cable ties (indicated by red arrows in the main internal photograph). Note that the Live and Neutral leads are secured to the mains output socket (SK1) using cable ties which pass through the holes in its moulding.

Testing

Before applying power, check your wiring very carefully and make sure that all mains connections are covered in heatshrink tubing. That done, check that there is a 10A fuse inside the fuseholder and note that IC1 should be left out of its socket for the time being.



Install the UHF receiver module with its crystal towards BCD switch S1, as shown here.

When testing and making adjustments, the UHF Remote Mains Switch will be operated with the lid open. **During this procedure, you MUST NOT touch any of the 230V AC wiring. This includes the transformer primary leads, plus all wiring to the mains socket, neon lamp, switch S5, the fuseholder, the relay and the mains terminal block.** Although all connections should be insulated, it's wise to be careful.

In particular, note that the relay's wiper (pole) contact, the fuseholder's terminals and the switch wiper will all be at 230V AC if the device is plugged into the mains, even if switch S5 is off.

If your house has a safety switch (earth leakage detection) installed, then this can provide added protection. If not, then consider using a portable safety trip-switch for this part of the test.

Powering-up

Apply power and use your DMM to check that there is 5V (4.9V to 5.1V is acceptable) between pins 14 and 5 of IC1's socket. If this is correct, switch off, **disconnect the mains plug from the wall socket** and install IC1. Take care to ensure that it goes in the right way round – see Fig.2.

Next, set the DMM to the 250V AC range, apply power again and carefully check the voltage between the Live and Neutral sides of the mains terminal block (ie, measure the mains voltage). That done, press switch S4 to turn on the relay, set your DMM to read volts DC and adjust multiturn trimpot VR1 so that the DC voltage between 'test points' TP1 and TP GND is 1% of the mains voltage reading.

For example, if the mains voltage is 250V AC then adjust VR1 for a reading at TP1 of 2.50V DC. Similarly, if the mains voltage is 230V AC, VR1 would be set for a reading of 2.30V at TP1.

Note that for a European mains voltage of 220V AC, VR1 should be adjusted so that TP1 reads 2.5V when the mains voltage is 220V AC. In other words, set VR1 so that the DC voltage at TP1 is 1.14% of the mains voltage. This will set the brownout cut-out to 192V AC.

Setting the BCD switches

If you intend using this unit with a water tank level meter base station,

Table 1: Setting The Timeout Period

Switch S3 Setting	Timeout Period (Minutes)
0	No timeout
1	1
2	2.55
3	4.5
4	5.5
5	6.75
6	10
7	15.5
8	30
9	45
A	60
B	90
C	120
D	150
E	180
F	240

Follow this table to adjust BCD switch S3 to set the required timeout period (if required). A setting of '0' gives no timeout period – ie, the unit will only switch off in response to an 'Off' signal from the transmitter or the Water Tank Level Meter Base Station.

Check These Important Safety Points

(1) Use the specified plastic case to house this project and note that the antenna must be fully enclosed inside the case. **DO NOT** use a metal case.

(2) Use mains-rated cable for all wiring connections and insulate all soldered terminals with heatshrink tubing. **Use fully-insulated spade crimp connectors** for all connections to the mains switch and relay, and be sure to use a ratchet-driven crimping tool to properly secure the spade lugs to the leads.

(3) Secure the mains wiring and all other wiring connections with cable ties (see photo), so that they cannot move if they come adrift. Make sure that the wiring to the mains output socket (SK1) is correct and that it is properly secured.

(4) All wiring to the mains switch, mains socket, neon indicator, relay contacts, the two-way terminal block and the transformer primary operates at 230V AC (ie,mains potential). Do not touch any of this wiring or the connections to any of these parts while this device is plugged into the mains. DO NOT attempt to build this device unless you know exactly what you are doing and are familiar with high-voltage wiring.

then you will have to set BCD switches S1 and S2 accordingly. It's just a matter of setting S1 to the pump number and S2 to the encode value to match both the Water Tank Level Meter and the Base Station.

BCD switch S3 sets the timing period – see Table 1. Usually, S3 is set to 0 for controlling pumps that deliver to a household water supply.

If pumping between tanks, then the timer can act as a back-up to switch off the pump if the level meter fails.

Output power at power-up

Another option is for the UHF Remote Mains Switch to apply power to the mains output socket (SK1) at power-up. This feature is handy if you want the unit to automatically supply power to an appliance when power is restored after a blackout; eg, to a pump that supplies water to a house.

To enable this option, all you have to do is press and hold down switch S4 when powering up the UHF Remote Mains Switch. Once enabled, exactly the same procedure is used to disable this option.

Your UHF Remote Mains Switch is now complete. **Be sure to disconnect the mains lead from the wall socket when fitting the lid** and be careful not to pinch any of the leads to the mains socket. Provided you've dressed the leads correctly and secured them with cable ties, the leads should fold back neatly into the case when the lid is placed in position.

Transmitter

Now then, what about the optional UHF transmitter unit. Well, that's fully described on pages 21 to 25.

They Won't Get Any Greener

TechnoTalk

Mark Nelson

Every week, comes more news of solid-state light devices replacing incandescent lamps. The time-served and trusted light bulb may soon disappear as rapidly and suddenly as the cathode ray tube has done in televisions and computer screens. Mark Nelson reports on some of the new applications.

I thought I'd end the year (at the time of publication) and start the New Year with a round-up of news about LEDs, and the way they are supplanting the traditional light bulb. As you will see, it's quite a colourful tale and, with no more ado, we'll start off with the colour green.

Dial green for go

"Come on, they won't get any greener!" is what Americans say if they are stopped at traffic signals and the driver in front is slow off the mark when the lights turn green.

But American traffic signals certainly are getting greener from an environmental viewpoint. New Mexico has just instituted a $3 billion scheme to replace more than 8,000 traffic lights with LED illumination, and this is just one of 38 states nationwide that are offering cash incentives to traffic authorities to retrofit traffic signals with LED lighting units.

All this is in the US, but the British angle is that it's a UK-based company that is grabbing the lion's share of this business. Dialight Corporation is the firm's name, and it was founded in 1938 to produce instrument panel lights for aircraft and motor vehicles. The Huntingdon-based company boasts that its LED traffic signals have saved municipalities millions of dollars in energy costs and maintenance, while the company's signal and marker lights for heavy-duty vehicles often outlast the vehicles themselves.

Easy to retrofit

Brian Todd, vice president at Dialight says, "LED traffic signals use 90 percent less energy and last ten times longer than traditional incandescent traffic signals, so they will bring major environmental benefits. The additional benefit of our modules is that they can be retrofitted easily into the existing enclosures of the current energy-inefficient incandescent lamps."

The grant that enabled New Mexico to fund the replacement is part of President Obama's recovery and investment fiscal stimulus programme, from which the city of Indianapolis is also using $2.1 million to replace outdated bulbs with more energy-efficient LED lights in its traffic signals.

In London, Mayor Boris Johnson announced last August a £2.4 million scheme to upgrade 3500 signals at 300 junctions with LEDs, saving 600 tonnes of carbon dioxide being released into the atmosphere. He hoped this would inspire other uses for LED lighting, stating: "We are pressing ahead to get many more of these illuminating orbs onto our streets to join a range of other energy-zapping measures already saving us money, such as solar-powered bus stops and shelters."

Analysts are optimistic that these contracts will trigger the start of a run of new contracts, with one commentator enthusing, "I think the LED lighting sector is going to become hot and that over the next year or two it could easily be worth double."

Affordability's the thing

The constant promise of lower lighting costs is all very well, but when will we see affordable LED light bulbs in the shops? Probably not for a while yet, although you can find plenty of mains voltage LED spotlights and downlighters on the web at prices just below the £10 mark. None of these look like a normal light bulb though, and I personally would not want one of these hideous items in my house.

Prices are clearly not ready to tumble while compact fluorescents are so cheap, but there are plenty of researchers aiming to consign CFL bulbs to the dustbin of history. For instance, in last April's issue, we mentioned the work of Prof. Colin Humphreys at Cambridge University, investigating a new breed of LED lamp bulbs that would last 60 years, and slash the proportion of electricity used for lighting from 20 to just five per cent, eliminating the need for eight power stations in Britain and 133 in the States.

His 'recipe' for super-efficient lights uses gallium nitride (GaN), coating blue LEDs with phosphors to produce white light. GaN LEDs have hit the market rapidly and are already widely used in flashlights and front bicycle lights, as backlighting for mobile phones and interior lighting in cars and aeroplanes. Looking ahead, Prof. Humphreys predicts that the timescale for the widespread adoption of GaN LEDs in homes and offices is probably as short as five to ten years.

A SAD story

Another field of research under the direction of Prof. Humphreys, at the Cambridge Centre for Gallium Nitride, is considering the possibility of using GaN LEDs to mimic sunlight, which could have important benefits for sufferers of seasonal affective disorder (SAD). SAD is a type of winter depression that affects an estimated half a million people in the UK every winter between September and April; in particular, during December, January and February.

It is caused by a biochemical imbalance in the brain due to the shortening of daylight hours and the lack of sunlight in winter. For many people, SAD is a seriously disabling illness, preventing them from functioning normally without continuous medical treatment. For others, it is a condition causing discomfort, but not severe suffering.

Often written off casually as the 'winter blues', it is estimated that a further 17 per cent of the UK population has this milder form of condition. More on the subject from the two voluntary organisations **www.sada.org.uk** and **www.sad.org.uk**.

Seeing blue

So what's the connection with LEDs? Simply that light therapy can mitigate the problem for many SAD sufferers, with clinical research showing that specifically blue light from the sky triggers our bodies to be active and energetic, also regulating our mood.

Blue LEDs can produce the same results artificially, and using an energy light for as little as 15 to 45 minutes a day can improve people's mood and energy level throughout the day. In practical terms, this takes the form of a panel of blue LEDs about six inches square, placed on the side of the user's desk or breakfast table. The Dutch company Philips has developed such a product. Called the goLITE BLU, it is highly practical and has good reviews on the Internet. At around £250 it seems excessively expensive. There are other products too; try googling for 'blue light SAD', but try to avoid quackery.

Feedback

The Nov '09 *Techno Talk* column dealt with 'ratters and rotters', and also how to dispose of electronic waste responsibly. I mentioned in passing the crossed-out wheelie bin symbol, and even as I wrote the piece, wondered if it had a proper name.

Well it certainly does, at least in Dutch. In English it is known more prosaically as the small hazardous waste symbol.

Fellow columnist, Alan Winstanley offers this feeback: "Today's useless information is that this symbol is called the KCA logo. KCA stands for 'klein chemisch afval' (small chemical waste) in Dutch. The Dutch and Germans are nuts about this sort of thing, as I found out in the 1990s when I took them to the European Court over similar anti-competitive trade labelling practices!"

Happy Christmas and a prosperous New Year to all fellow Techno Talkers!

UHF Remote Mains Switch Transmitter

Designed to control the UHF Remote Mains Switch, this handheld transmitter can operate over a 200m range. It's based on a PIC micro and a pre-assembled transmitter module, making it easy to build and get going.

By JOHN CLARKE

IF YOU want to control the UHF Remote Mains Switch in a stand-alone application, then you need to also build this UHF transmitter. As shown in the photos, it's housed in a plastic case with two push-button switches for on/off switching.

Press the 'On' button and power is applied to the mains output socket on the UHF Remote Mains Switch. Alternatively, press the 'Off' button and the power turns off. What could be easier?

ID code

The front panel also provides access to a small rotary switch. This selects one of 10 'identities', which means that the transmitter can control up to 10 separate UHF Remote Mains Switches. This rotary switch is adjusted using a small blade screwdriver.

Immediately above the 'On' button is a 'transmit indicator' LED. This briefly lights each time a transmission is sent (ie, whenever the on or off buttons are pressed). However, if there is an error, this LED will flash three times in a 1.5-second period.

Typically, an error will be indicated if both switches are pressed simultaneously, or if a switch is pressed too briefly. In either case, it's simply a matter of pressing the desired switch again to send the control signal.

How it works

Refer now to Fig.1 for the circuit details. As mentioned earlier, it's based on a PIC microcontroller (IC1) and a 433MHz transmitter module.

Under normal conditions (ie, when no signal is being transmitted) no power is applied to the circuit. This means that battery usage is kept to an absolute minimum.

Pressing either switch S1 (On) or switch S2 (Off) connects the battery's positive terminal to regulator REG1 via diode D1 or D2. A 10Ω resistor is included between the battery and the switches to limit the initial charge current to the 10μF bypass capacitor at REG1's input. This minimises wear on the switch contacts.

As soon as power is applied to REG1's input, its output delivers a +5V rail to pin 14 (Vdd) of IC1. As a result, the program within IC1 starts running. One of the first things it does is to check which switch was pressed, and this happens after a short delay to ensure that the switch is fully closed.

In operation, S1 is monitored via a 10kΩ resistor at the RA2 input, while S2 is monitored via a 10kΩ resistor at the RA4 input. The program first checks to see if S1 is closed and it does this as follows.

Initially, RA2 (pin 1) is set as an output with this pin at 0V. RA2 is then set as an input and its voltage checked to see if it is still at 0V or if it has been pulled to +5V. If it is at +5V, then S1 (On) is closed and the battery voltage is being applied to REG1 via diode D1.

The 10kΩ resistor in series with RA2 is included to limit the current into this input when its internal clamping diode conducts. This diode prevents RA2 from going more than 0.6V above

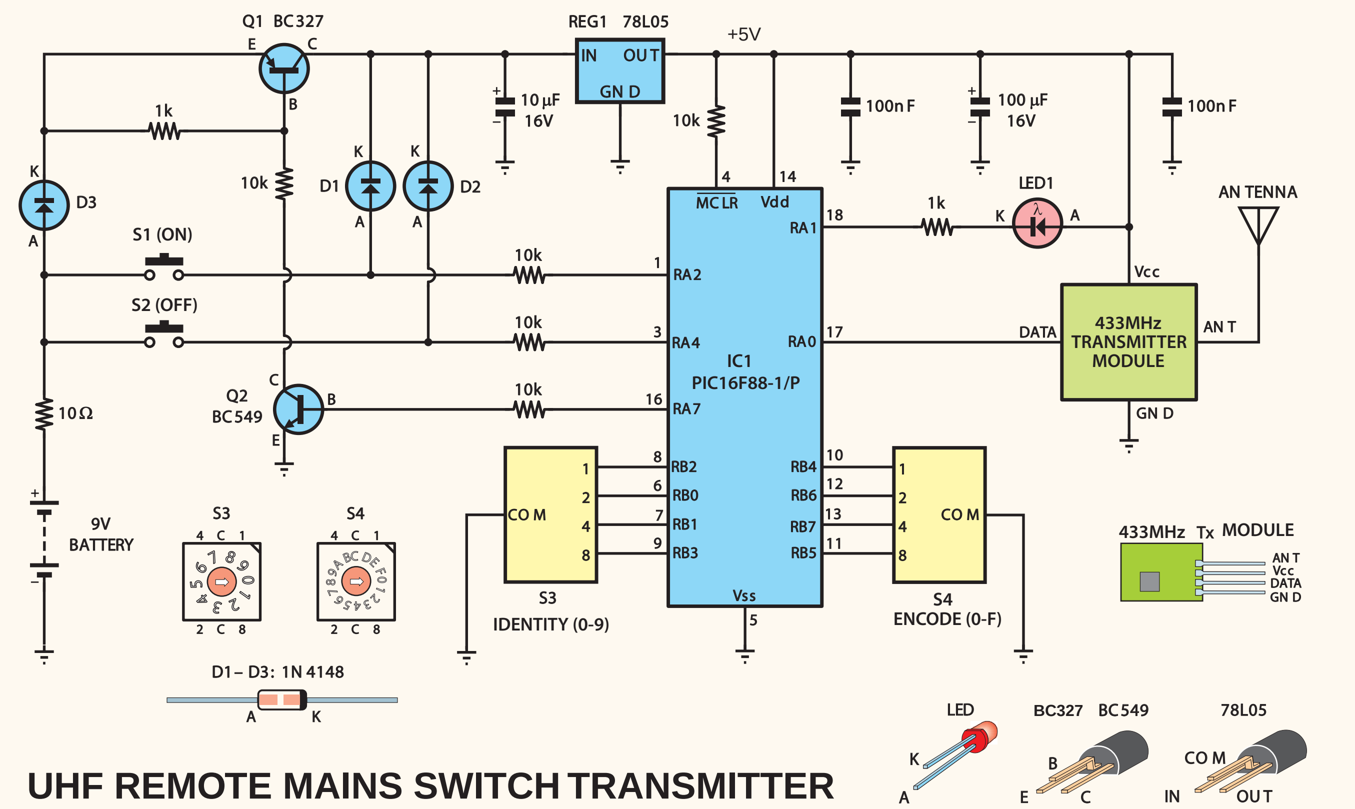


Fig.1: the transmitter circuit uses PIC microcontroller IC1 to generate a data signal whenever switch S1 (On) or S2 (Off) is pressed. This data is then fed via IC1's RA0 output to a 433MHz transmitter module. BCD switches S3 and S4 set the identity and encode values, and must be set to match the settings in the UHF Remote Mains Switch.

the +5V supply, thereby protecting this input from damage.

Next, the program checks to see if S2 is closed. In this case, RA4 (pin 3) is initially held low (0V) as an output. RA4 is then set as an input and its voltage checked. A high voltage means that S2 is closed and that voltage is being applied to REG1 via diode D2.

Diodes D1 and D2 provide reverse polarity protection for REG1 if the battery is connected the wrong way round. They also isolate the switch actions, so that RA2 will only go high if S1 is pressed and RA4 will only go high if S2 is pressed.

As well as detecting which switch was pressed, IC1's firmware also detects whether both switches were pressed simultaneously (as indicated by a high at both RA2 and RA4). It also detects if neither switch is pressed. In the latter case, this would mean that one of the switches was pressed but then released before the program had a chance to check which switch it was.

Next, the program sets RA7 (pin 16) of IC1 high, and this drives the base (B) of transistor Q2 via a 10kΩ resistor. As a result, Q2 turns on and supplies base current to Q1, which also turns on.

As a result, the supply current can now flow through D3 and Q1 to REG1, which means that power to REG1 is maintained even if switch S1 or S2 is released. This supply latching is necessary to allow time for the 'on' or 'off' code to be transmitted in its entirety without supply interruption.

Diode D3 is there to protect the circuit from reverse battery connection.

Port RA1 (pin 18) is the transmit indicator output. This output goes low during code transmission and turns on LED1 via a 1kΩ resistor. However, if the program detects that both switches were pressed, or if it detects that neither switch was pressed (ie, the press was too brief), the LED flashes three times to indicate an error.

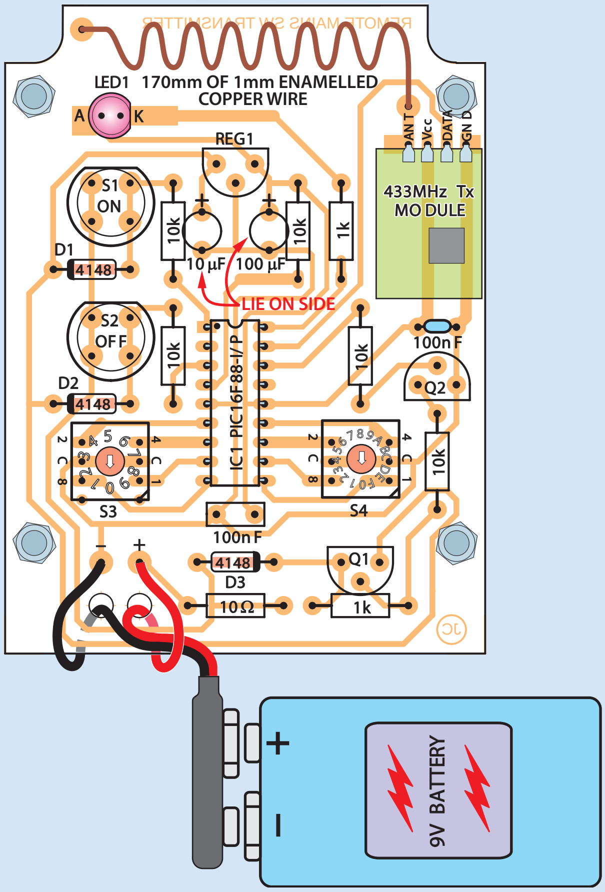
Main Features

- Controls the UHF Remote Mains Switch
- Up to 10 UHF Remote Mains Switch units can be controlled
- 16 encoder selections
- 200m range
- On/off switching
- Handheld operation
- 9V battery supply
- Transmit indicator
- Transmit error indication

BCD switches

Now let's take a look at the two binary coded decimal (BCD) switches (S3 and S4) that are connected to the microcontroller.

First, BCD switch S3 sets the identity. It's connected to IC1's RB0



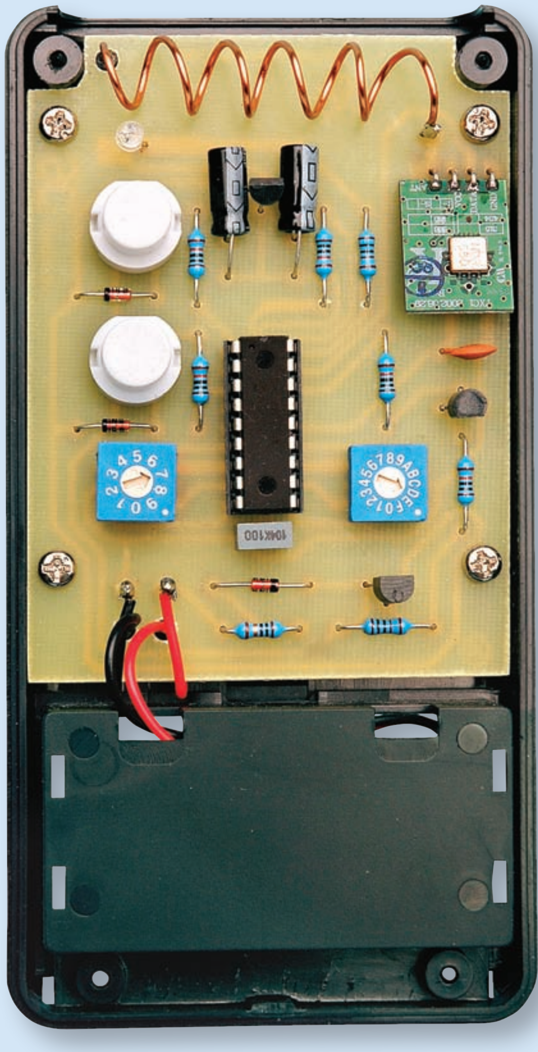


Fig.2: follow this diagram to install the parts on the PC board and complete the battery wiring. Note that BCD switch S3 is installed in a socket to raise it up off the PC board (see text) to make it easier to access. The view at right shows the completed PC board mounted inside the handheld case.

to RB3 inputs and individually connects these inputs to ground when its 2, 4, 1 and 8 switches are closed respectively.

Basically, S3 is arranged as a rotary switch, with 10 settings ranging from 0 to 9. For the '0' setting, all switches are open, while for the other numbers, different combinations of switches are open and closed. For example, a '1' position ties the RB2 input to ground.

Conversely, the RB0 to RB3 inputs are pulled to the +5V supply rail when their corresponding switch is open. That's because each input has an internal pull-up resistor of about 20kΩ. In operation, S3's settings can be read by microcontroller IC1 because a low voltage on one of the inputs means that its corresponding switch is closed, while a high voltage means that the switch is open.

BCD switch S4 sets the encode number and is monitored in a similar way. However, this switch has six extra positions, labelled A to F, giving it a total of 16 positions.

The settings for S3 and S4 are sent as part of the on/off code that's fed from RA0 to the 433MHz transmitter module. Basically, the UHF transmitter transmits a modulated signal when data is applied to its data input. A ¼-wave dipole antenna is connected to the transmitter's output.

In practice, IC1's RA0 output can generate on/off signals for up to 10 UHF Remote Mains Switches, depending on the setting of S3 (identity). Initially, a 50ms transmission is sent to set up the receiver so that it is ready to accept data. A 16ms locking signal is then sent, followed by 4-bit encode and 4-bit identity numbers.

Next, an 8-bit on/off signal is sent – either a value of 162 for 'on' or a value of 150 for 'off'. An 8-bit stop code with a value of 204 completes the data transmission.

Once this data has been sent, IC1's RA7 output is set low to switch off transistors Q2 and Q1. This ensures that the supply to REG1 turns off (assuming that switches S1 and S2 are both open). In addition, the RA1 output is taken to +5V to switch off LED1.

Finally, note the decoupling capacitors at the output of REG1. These filter the supply rails for IC1 and the 433MHz transmitter module.

Software

The software files will be available via the *EPE* Library site, accessed via **www.epemag.com**. Pre-programmed PICs will also be available from Magenta Electronics – see their advert in this issue for contact details.

Construction

The assembly is straightforward, with all parts, except the battery, mounted on a single PC board, code 739, measuring

86mm × 64mm. This is housed in a remote control case that measures 135 × 70 × 24mm.

Fig.2 shows the board component layout. Begin construction by checking the PC board for any defects, such as shorted tracks or breaks in the copper. That done, check the hole sizes. The four corner mounting holes should be 3mm in diameter, as should the two holes used to anchor the battery-snap leads.

Now for the assembly. Install the resistors first, taking care to place each in its correct position. It's a good idea to use a DMM to check each resistor value before installing it on the board.

Next, install the PC solder stakes for the battery snap leads and for the antenna connection near the 433MHz transmitter module. That done, install diodes D1 to D3, REG1 and transistor Q1 and Q2. Be sure to orient the diodes and transistors correctly, and don't get Q1 and Q2 mixed up. They may look the same, but Q1 is a BC327 *PNP* type, while Q2 is a BC549 *NPN* transistor.

Next, the capacitors; note that the 100nF ceramic capacitor mounts between Q2 and the transmitter module, while the 100nF polyester capacitor is located just below IC1. In addition, the two electrolytic capacitors adjacent to REG1 need to lie on their side, to clear the lid of the case – see photo.

Parts List

1 PC board, code 739, available from the *EPE PCB* Service, size 86mm × 64mm
1 remote control case, 135mm × 70mm × 24mm
1 433MHz UHF data transmitter (Jaycar ZW-3100 or equivalent)
1 9V battery
1 18-pin DIL socket
1 6-pin DIL socket (or 8-pin)
2 click-action momentary switches (S1, S2)
1 0-9 BCD DIL PC-mount switch (S3)
1 0 to F BCD DIL PC-mount switch (S4)
4 M4 × 10mm screws
1 170mm length of 1mm enamelled copper wire
1 9V battery snap connector
3 PC stakes

Semiconductors
1 PIC16F88-I/P microcontroller, programmed with 1020208A. hex (IC1)
1 BC327 *PNP* transistor (Q1)
1 BC549 *NPN* transistor (Q2)
1 78L05 5V regulator (REG1)
3 1N4148 signal diodes (D1 to D3)
1 3mm red LED (LED1)

Capacitors
1 100µF 16V PC electrolytic
1 10µF 16V PC electrolytic
1 100nF MKT polyester (code 104 or 100n)
1 100nF ceramic (code 104 or 100n)

Resistors (0.25W, 1% metal film)
5 10kΩ   1 10Ω
2 1kΩ

Switch mounting

Switches S1 and S2 can now go in. Be sure to mount these with their flat sides positioned as shown in Fig.2 (ie, towards the top edge of the PC board). That done, install an IC socket for IC1 (notched end towards REG1), but don't install the IC at this stage.

BCD switch S3 also mounts in an IC socket, so that it is raised off the board to make it easier to adjust from outside the case. One option here is to fit a cut-down 8-pin DIP socket, with three pins on each side. Alternatively, we've provided two extra holes on the PC board so that it will accept a standard 8-pin DIP socket.

Once the socket is in place, install S3 with its orientation dot at bottom right – see Fig.2 and photo. If you have fitted an 8-pin socket, be sure to plug S3 into the top six pins – the two pins nearest the battery terminals are unused.

By contrast, BCD switch S4 mounts directly on the PC board. Once again, be sure to mount it with the correct orientation – see Fig.2 and photo.

The UHF transmitter module can now be installed. This is done by first placing it in position, then bending it down so that its top edge is about 8mm above the top of the main PC board. That done, check that it is correctly oriented before soldering its pins.

LED1 must be installed so that the top of its lens is 14mm above the PC board (ie, level with the switch top). Be sure to orient it with its anode lead (the longer of the two) to the left.

The board assembly can now be completed by installing the antenna coil. This is made from a 170mm length of 1mm enamelled copper wire (ECW).

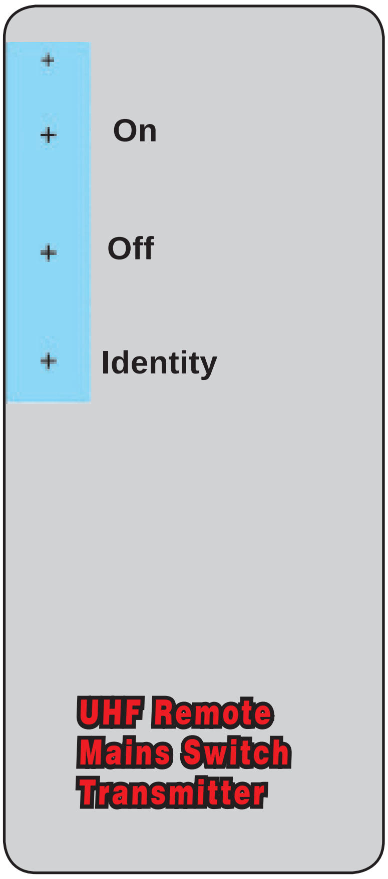


Fig.3: this full-size artwork can be used as a drilling template for the front panel.

First, cut the wire to length and scrape away about 3mm of insulation at each end, then shape the wire into a spiral by winding it around an 8mm former. Once that's done, solder one end of the antenna coil to the antenna PC solder stake and the other end directly to the PC board – see photo.

Final assembly

The final assembly basically involves fitting the board inside the case. The first step is to feed the battery-snap leads through from inside the battery compartment and then down through the two holes in the PC board – see Fig.2. That done, solder the leads to their respective PC stakes, taking care to ensure that the polarity is correct.

Now connect the battery and check that the voltage between pins 14 and 5 of IC1's socket is close to 5V when switch S1 is pressed. If this is correct, install IC1 in its socket, with its notched end towards REG1. LED1 should now briefly light each time S1 or S2 is

pressed. If it doesn't, check the LED's orientation.

Assuming all is well, the PC board can now be fitted into the base of the case. It's secured to the four integral stand-offs using M3 × 6mm screws. That done, set the identity and encode switches to match those in the *UHF Remote Mains Switch*.

Testing

Now check that the UHF Transmitter controls the UHF Remote Mains Switch by pressing the On and Off buttons. The neon indicator below the mains socket should come on when the transmitter's On button is pressed, and go out when the Off button is pressed.

If it doesn't work, unplug the UHF Remote Mains Switch from the wall socket and check the identity and encode switch settings in the two units. If it still doesn't work, go over the transmitter assembly carefully and check for errors.

Note also that the transmitter will not operate the UHF Remote Mains Switch if they are too close to each other. The two units must be separated by at least one metre.

Boxing-up

Once everything is working, attach the lid to the transmitter case.

The holes in the case can be drilled using the front panel label shown in Fig.3 as a template. You will need to drill two 10mm holes to clear the switch caps, a 3mm hole for the LED and a 9mm hole to give access to the Identity switch (S3) (note: the latter is not necessary if you intend using the transmitter with just one UHF Remote Mains Switch).

It's best to make the larger holes by first drilling small pilot holes, which can then be further drilled out to about 5mm. These holes can then be carefully reamed out to their correct sizes.

That done, the front-panel artwork (Fig.3) can be attached to the lid of the case using an even smear of clear silicone sealant.

That's it – your UHF Remote Mains Switch Transmitter is now complete and ready for action. ***EPE***

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By MAURO GRASSI

Playback adapter for CD-ROM drives – Part 2

Last month, we published the circuit details of our new CD-ROM Player Adapter and described its operation. This month, we show you how to build it.

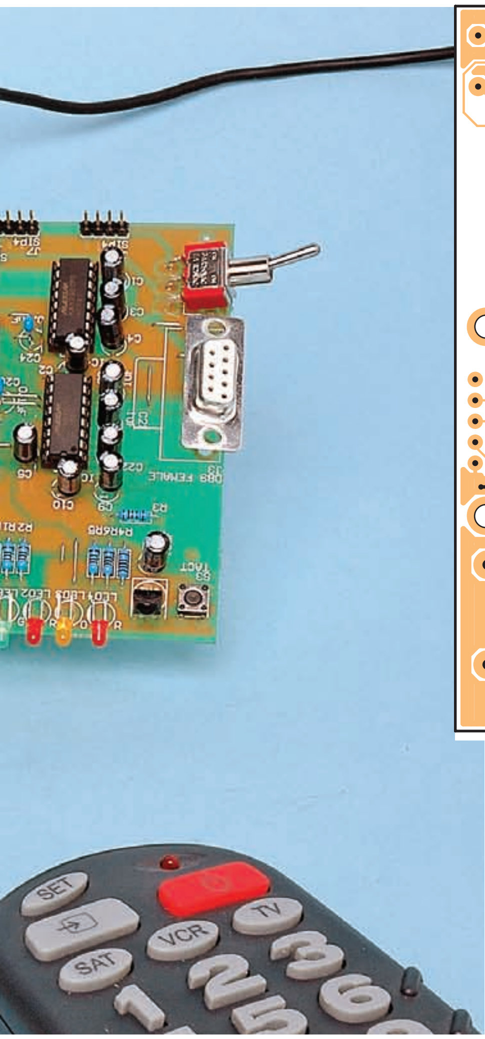
TO KEEP costs down, we've designed a single-sided PC board for this project. This board is coded 740 and measures 136mm × 97mm. The complete board and the CD-ROM drives could optionally be encased in a plastic case or mini-tower computer case, along with the power supply.

Because it's single-sided, the PC board is somewhat larger than a double-sided board would be and there are quite a few wire links that have to be installed.

Before installing any parts though, do inspect the PC board for hairline cracks in the copper tracks or shorts. Some of the tracks are very fine and quite close together, so check carefully.

Installing the wire links

Fig.2 shows the locations of the wire links and these should all be installed first. Because some of these links are quite close together, it's essential that they be perfectly straight so that they don't short together.



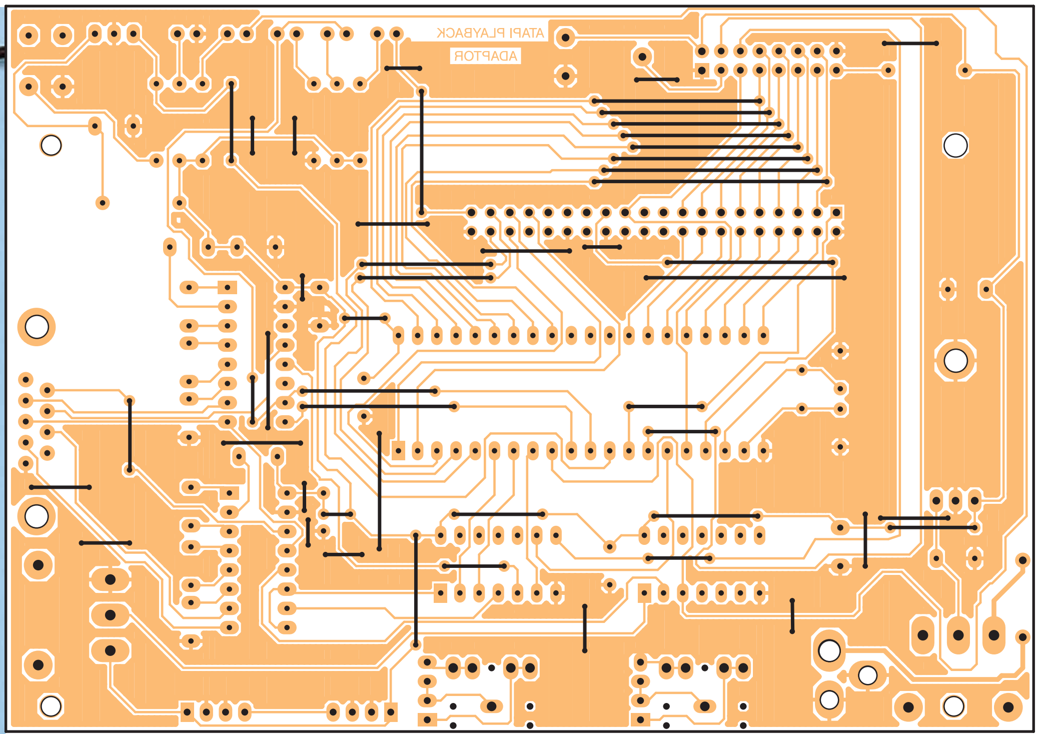


Fig.2: the first job in the assembly is to install all the wire links as shown here. Make sure that these links are straight, to prevent shorts – see text.

The best way to straighten the link wire is to stretch it slightly by clamping one end in a vice and pulling on the other end using a pair of pliers. Each wire link can then be cut to length and its ends bent down at right-angles using needle-nose pliers before mounting it on the PC board.

Once you've completed this task, you're ready to install the remaining parts. Fig.3 shows the parts layout on the board.

Start with the resistors, taking care to ensure that the correct value is used at each location. Table 1 shows the resistor colour codes, but it's also a good idea to check each one using a DMM (digital multimeter) before soldering it on to the PC board.

Next, solder in protection diode D1, making sure that it is oriented correctly, then install the small tactile switch (S3). The latter only fits correctly if it is the right way around.

The next step is to solder in the 40-pin IC socket for the microcontroller, plus the two 14-pin and two 16-pin DIP sockets for the other ICs. Note that only IC1, IC2 and IC3 are required for normal operation, while IC4 and IC5 are required only if you are planning to program the micro via this board. Make sure that the sockets are all oriented correctly – ie, with their notched ends arranged as shown on Fig.3.

The TO-220 regulator (REG1) is next on the list. As shown, this part is fitted with a small heatsink and is mounted horizontally on the PC board.

Programming The Microcontroller

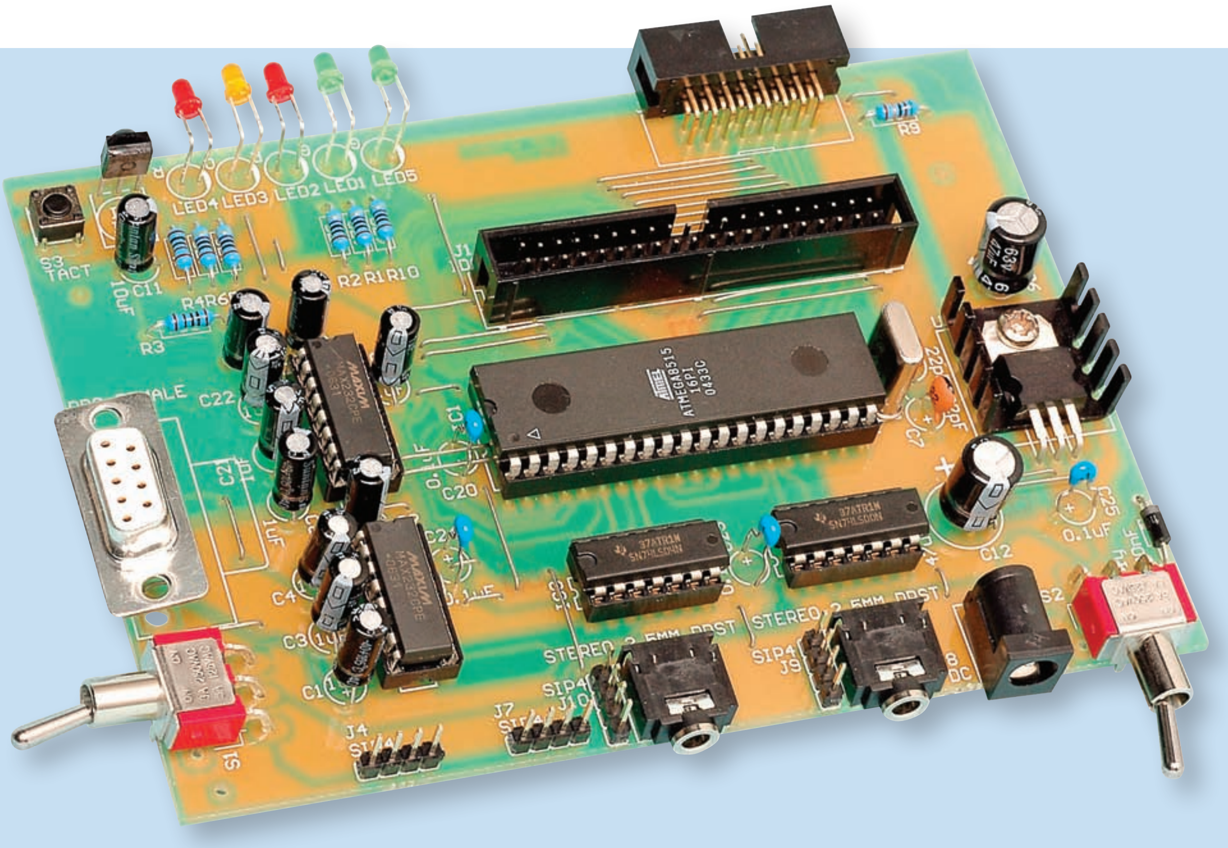
IF you purchase a kit, then the microcontroller will be supplied pre-programmed. If not, then you will have to programme it yourself or purchase a pre-programmed chip from Magenta.

To programme it yourself, you will need to install both IC4 and IC5 (MAX232), as well as the other two logic ICs. You then load the hex file into Pony Prog 2000 and write to flash. If you don't already have this program, it is available as a free download from **www.lancos.com/ppwin95.html**.

You will need to first flick switch S1 and make sure the orange LED lights up. The micro is then ready to be programmed. We should also mention that if you are using Pony Prog 2000, you must change the setting under Setup -> Interface Setup and make sure that the only box that is ticked is the 'Invert Reset' box. Then select the correct device by going to Device -> AVR -> Atmega8515.

Prior to programming, Pony Prog 2000 needs to be calibrated for correct timing. To do this, simply go to Setup -> Calibration. This only needs to be done the first time you run Pony Prog 2000 on a new computer.

Now choose File -> Open Program (FLASH) File and select your hex file. Go to Command -> Program (FLASH) and Pony Prog 2000 should start programming your micro. Once programming is complete, you should flick switch S1 so that the orange LED goes out and then the firmware should start running.



This view shows the fully assembled prototype PC board. Note that the two MAX232 ICs and the DB9 socket (CON3) are only necessary if you intend programming the microcontroller on the board. Note also that trimpot VR1 (contrast) and several wire links were added to the board after this photo was taken.

The correct procedure here is to first bend the regulator's leads down though 90°, exactly 5mm from its body. That done, the device and its heatsink are fastened to the PC board using an M3 × 10mm screw and nut. The leads are then soldered.

Don't solder the leads before bolting the device to the PC board. If you do, you could stress and break the PC tracks as the device is tightened down on the board.

Trimpot VR1 can go in next, followed by the 2.5mm DC socket (CON6) and the electrolytic capacitors. The latter are polarised, so make sure they go in the right way around.

Now solder in the 100nF bypass capacitors. Take particular care with the 100nF capacitor immediately to the left of IC1. It straddles a couple of wire links and should be mounted proud of the board so that its leads don't short against these links. The other 100nF capacitors can be pushed all the way down onto the board.

LED mounting

The five LEDs (LEDs 1 to 5) and the infrared receiver module (IRD1) can now be installed. As shown in the photos, the LEDs all go in with their leads bent at right angles and are mounted about 5mm proud of the PC board. A cardboard spacer cut to 5mm makes a handy gauge when it comes to bending the LED leads – spacing them evenly off the board, so that they all line up.

Take care to ensure that the LEDs all go in the right way around. Just remember that the anode (A) lead is always the longer of the two, and that the cathode (K) lead usually has a 'flat' on the package body next to it.

IRD1 can be mounted so that its lens lines up with the centres of the LEDs. It must be oriented so that its lens faces out from the PC board.

Installing the headers

The next job is to solder in the 16-pin and 40-pin IDC headers. Pin 1 of each of these is indicated by an arrow on the side of the header and this corresponds to the square pad on the PC board. Be sure to get them the right way around.

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	1kΩ	brown black red brown	brown black black brown brown
❏	5	470Ω	yellow violet brown brown	yellow violet black black brown
❏	1	100Ω	brown black brown brown	brown black black black brown
❏	1	51Ω	green brown black brown	green brown black gold brown

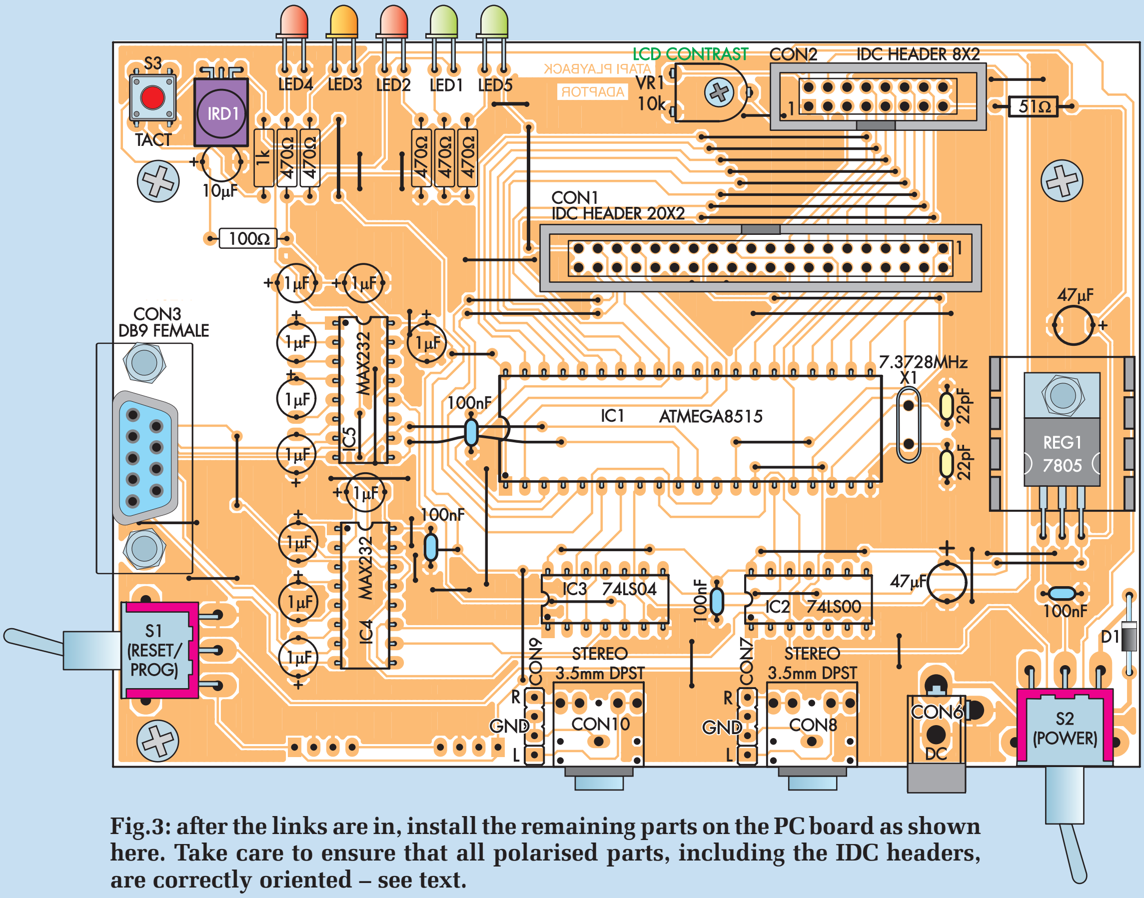


Fig.3: after the links are in, install the remaining parts on the PC board as shown here. Take care to ensure that all polarised parts, including the IDC headers, are correctly oriented – see text.

In each case, it's a good idea to initially solder just two pins of the header and then check that it is sitting flat against the PC board. After that, it's a routine job to solder the rest of the pins.

Finally, complete the PC board assembly by installing the 7.3728MHz crystal (it can go in either way), the two 22pF capacitors, the DB9 serial port connector (CON3), the two stereo jack sockets (CON8 and CON10), the two 4-way SIL pin headers (CON7 and CON9) and the two toggle switches.

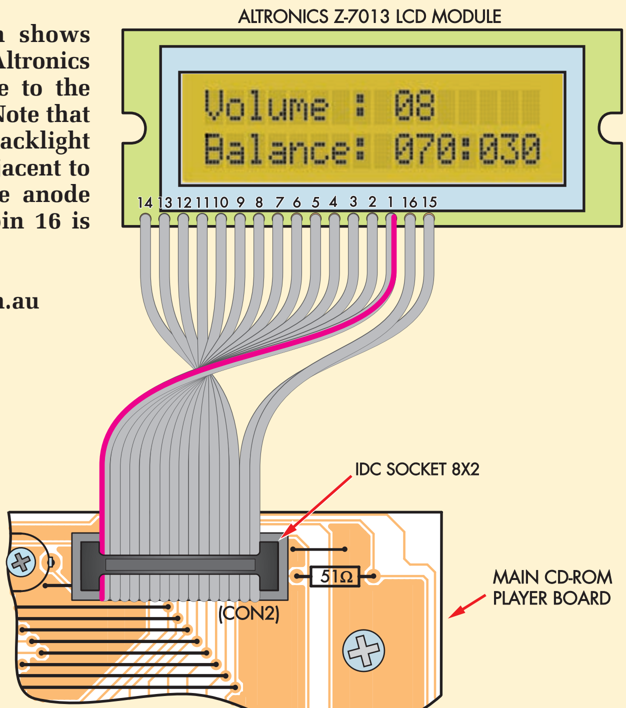
Connecting the LCD module

The LCD module to use must conform to the Hitachi HD44780 industry standard. This has an interface consisting of 16 or 14 lines, depending on how the LED backlight is connected.

A 16-way (or 14-way) ribbon cable is used to make the connection to the LCD module, and this is terminated at the other end in a 16-way IDC line socket, with the red stripe on the cable going to pin 1. This end then plugs directly into the 16-way IDC header on the PC board.

Fig.4: this diagram shows how to connect the *Altronics Z-7013 LCD module to the 16-pin IDC socket. Note that pins 15 and 16 (the backlight connections) are adjacent to pin 1. Pin 15 is the anode connection, while pin 16 is the cathode.

***www.altronics.com.au**



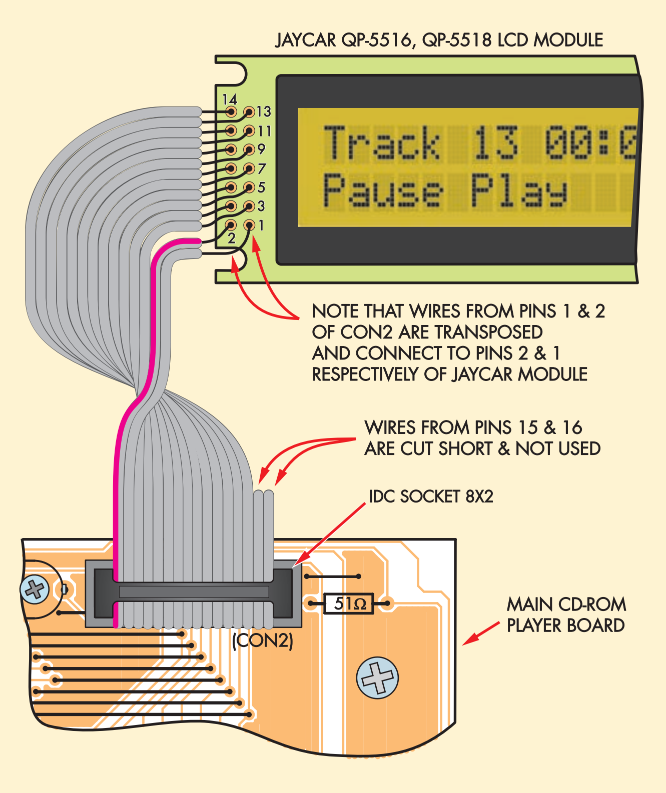


Fig.5: connect the Jaycar LCD modules as shown in this wiring diagram. Note particularly that the wires from pins 1 and 2 of header CON2 are transposed at the LCD module (ie, pin 1 goes to pin 2, while pin 2 goes to pin 1).

Fig.6: assigning the buttons on the remote for the various functions is easy – just follow the prompts on the LCD readout. This is the prompt for assigning the 'Volume Up' button.

Fig.4 shows the connections to the Altronics Z-7013 LCD module. This device has 16 pins all in one line along the bottom edge of the board (although pins 15 and 16 are adjacent to pin 1).

Alternatively, the Jaycar QP-5516 and QP-5518 LCD modules each have a 2 × 7-pin arrangement at one end; ie, there are only 14 connections. The backlight connections are made on the module itself, so pins 15 and 16 of CON2 are not connected in this case. Fig.5 shows the wiring connections for the specified Jaycar modules.

In particular, note that pin 1 on the Jaycar modules is the +5V connection, while pin 2 is the 0V connection. It's the other way around on the Altronics module, where pin 1 is 0V and pin 2 is +5V.

Software

The software files will be available via the *EPE* Library site, accessed via **www.epemag.com**. Pre-programmed Atmel micros will also be available from Magenta Electronics – see their advert in this issue for contact details.

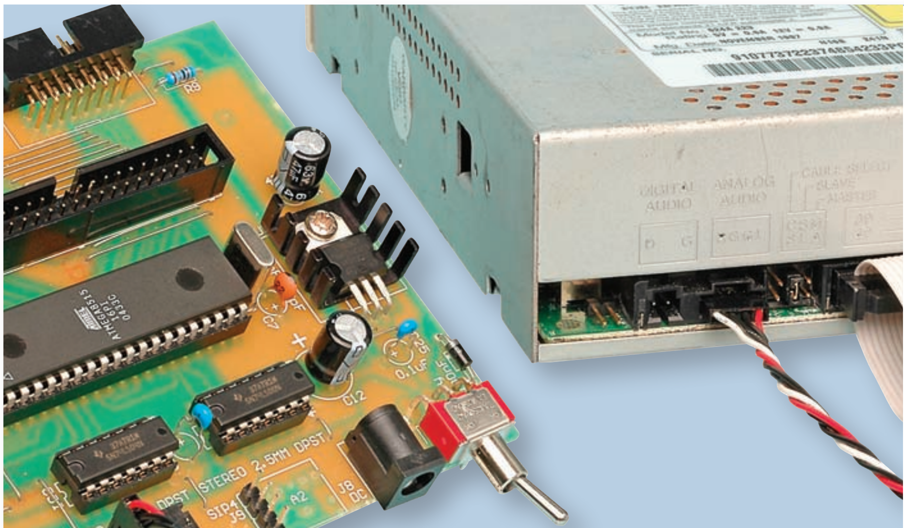
Testing and troubleshooting

Great care has been taken to ensure that the firmware is free from bugs, but we cannot guarantee that it will work with every CD-ROM drive. We did test the board with six different CD-ROM drives and it worked well.

The only problem was that two of the drives did not respond to the volume change command. However, we are not sure that these two drives were actually functioning correctly all of the time, as they appeared to have intermittent faults.

Whichever drive you want to use for this project, make sure it is an ATAPI device (check that the IDC connector on the back of the drive has 40 pins, as opposed to 50 pins for a SCSI connector). Note also that the adapter will not work with some smaller form factor CD-ROM drives which have 44-pin connectors (akin to the 2.5-inch notebook hard drives).

Before plugging in the micro (IC1), the first thing to do is to check the



The audio output at the back of a CD-ROM drives can be connected to CON7 or CON9 via a standard 4-way cable fitted with matching headers. These cables are readily available from computer stores or you can make your own.

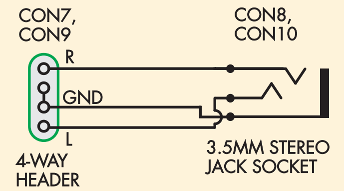


Fig.7: 4-way headers CON7 and CON9 are connected to the two 3.5mm stereo jack sockets. This makes it easy to connect to CD-ROM drive audio outputs via a standard stereo jack plug.

Table 3: CON2 Pin Assignments

Pin	Pin	Description
1	V_{SS}	Supply rail for module; typically GND
2	V_{DD}	Supply rail for module; typically +5V
3	V0	Set LCD contrast
4	RS	RS = 0 selects instruction; RS = 1 selects data
5	R/W	R/W = 0 selects write; R/W = 1 selects read
6	E	E = 1 selects the LCD module
7	D0	Data bus bit 0
8	D1	Data bus bit 1
9	D2	Data bus bit 2
10	D3	Data bus bit 3
11	D4	Data bus bit 4
12	D5	Data bus bit 5
13	D6	Data bus bit 6
14	D7	Data bus bit 7
15	A	LED backlight anode
16	K	LED backlight cathode

power supply rails. To do this, first connect a 9V or 12V DC plugpack to the DC socket (CON6) and switch on. That done, check that the OUT terminal of REG1 is at +5V with respect to ground. Similarly, you should be able to measure +5V on pin 40 of the 40-pin socket, while pin 20 should be at 0V.

If these checks are OK, switch off and plug in the micro. Make sure that this device is oriented correctly and that all its pins go into the socket. In particular, take care to ensure that none of the pins are folded back under the device.

That done, set trimpot VR1 to mid-range and switch on again. Check that the LCD module initialises correctly, then adjust VR1 for optimum display contrast.

Remote control functions

The firmware has an option that allows you to use any RC5 protocol remote control. That means that you can use virtually any universal remote control, plus most of the remotes that are commonly used with TV sets, VCRs and DVD players.

Parts List – CD-ROM Controller

1 PC board, code 740, available from the *EPE PCB Service*, 136 mm × 97mm
1 16×2 backlit LCD module (Jaycar QP-5516 or QP-5518, Altronics Z-7013)
1 PC-mount 40-pin IDC header (CON1)
1 PC-mount 90° 16-pin IDC header (CON2)
1 PC-mount DB9 female RS-232 socket (CON3) (optional for programming)
1 28-pin or 40-pin SIL header strip
1 16-way IDC ribbon cable (to connect LCD module, length to suit)
1 16-way IDC line socket
1 40-way IDE HDD cable (to connect CD-ROM drives)
2 3.5mm stereo sockets, PC-mount (CON8,10)
1 2.5mm DC power socket, PC-mount (CON6)
1 PC-mount micro tactile switch (S3)
2 SPDT 90° PC-mount toggle switches (S1, S2)
2 16-pin IC sockets (optional for programming)
1 40-pin IC socket
2 14-pin IC sockets
1 TO-220 mini finned heatsink
1 7.3728MHz crystal (X1)
1 10kΩ horizontal trimpot (VR1)
1.5m tinned copper wire for links
1 M3 × 10mm machine screw
1 M3 nut

Semiconductors
1 ATMega 8515 microcontroller, programmed with CDATA.hex (IC1)
1 74LS00 quad NAND gate (IC2)
1 74LS04 hex inverter (IC3)
2 MAX232 RS-232 transceivers (IC4,IC5) (optional – see text)
1 infrared receiver module (IRD1) (Jaycar ZD-1952)
1 7805 3-terminal regulator (REG1)
1 1N4004 400V 1A rect. diode (D1)
2 3mm green LEDs (LED1,LED5)
2 3mm red LEDs (LED2,LED4)
1 3mm orange LED (LED3)

Capacitors
2 47µF 16V electrolytic
1 10µF 16V electrolytic
10 1µF 63V electrolytic (optional for programming)
4 100nF monolithic
2 22pF ceramic

Resistors (0.25W, 1%)
1 1kΩ
1 100Ω
5 470Ω
1 51Ω

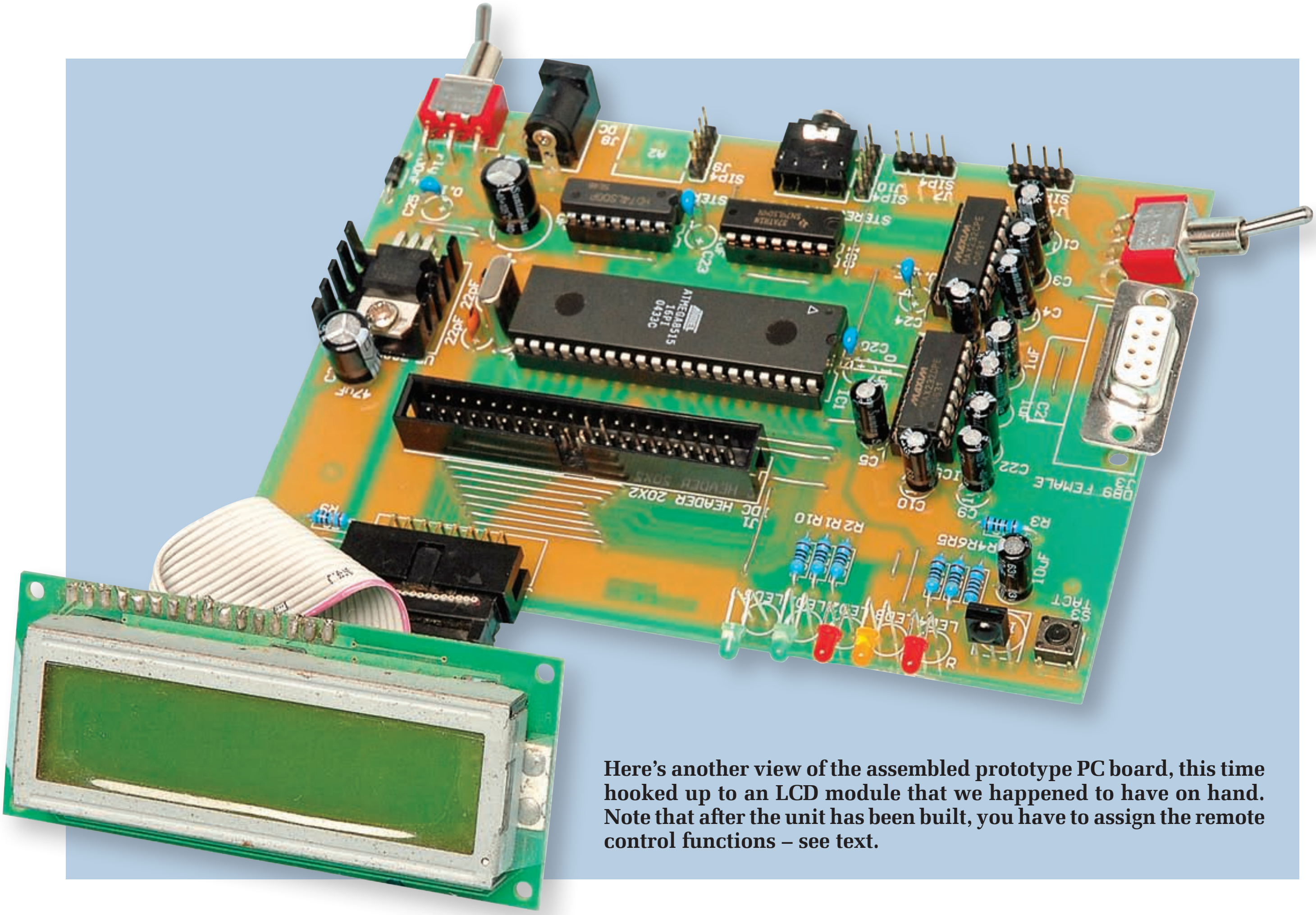
Power Supply Options

Last month, we stated that one of the supply options for the board was to plug a computer power supply into either CON4 or CON5. We have since decided to scrap that option and now recommend that you stick to powering the board from a 9V or 12V DC plugpack.

The disk drives can be powered directly from a computer power supply. Alternatively, if you don't want the fan noise of a computer power supply, you can use a mains adaptor like the Jentec JTA0202Y. This unit supplies +12V and +5V rails at 2A each, which is enough to power two drives and comes with the correct plug (you'll need a Y-splitter cable to power two drives).

You purchase this adaptor via eBay.

The first step is to assign the buttons that will control the various functions. To do this, you first need to press and hold the 'Remote Program' button (S3) while the device resets. To get the device to reset, you toggle switch S1 so that the orange LED lights and then toggle it again to turn the LED off (ie,



Here's another view of the assembled prototype PC board, this time hooked up to an LCD module that we happened to have on hand. Note that after the unit has been built, you have to assign the remote control functions – see text.

you hold S3 down while you toggle S1 twice).

This resets the micro and takes you to the 'Setup Remote' screen. Here you program the keys used for the project. The device will guide you through the set-up, and the keys that you define will be stored in EEPROM for later use.

For example, when the screen displays 'Press Vol Up' (see Fig.6), you simply press the 'Volume Up' button on your remote. It's just a matter of cycling through all the options until the button assignment has been completed.

This means that you can use any spare RC5 remote and define the keys as you see fit. The 'Power' button is deliberately unused for this project, and this lets you control the device with your TV remote control, for example.

In other words, because the 'Power' button is unused, you can have your TV off and use its remote to control the CD-ROM Player Adapter. Then, when you are finished with the adaptor, you can switch it off and use the remote to control your TV again.

Of course, you won't be able to play a CD and watch your TV simultaneously using the same remote, but this feature can keep costs down. It means that you don't have to purchase a separate universal remote control, although you can if you wish.

Operation

The user interface has been kept quite simple. Occasionally, issuing a command will result in an error screen. This is perfectly OK as the firmware has been designed to be quite tolerant of errors. If it happens, simply try the command again, but if the problem persists, it may indicate an incompatibility or fault with your drive.

The 'Error' screen typically looks like that shown in Fig.2 last month, but may have different numbers that are used for debugging purposes. The hexadecimal numbers give an indication of the state of the ATA registers and the state of the machine when the error occurred.

If the errors consistently re-occur, this information will help to diagnose the problem. *EPE*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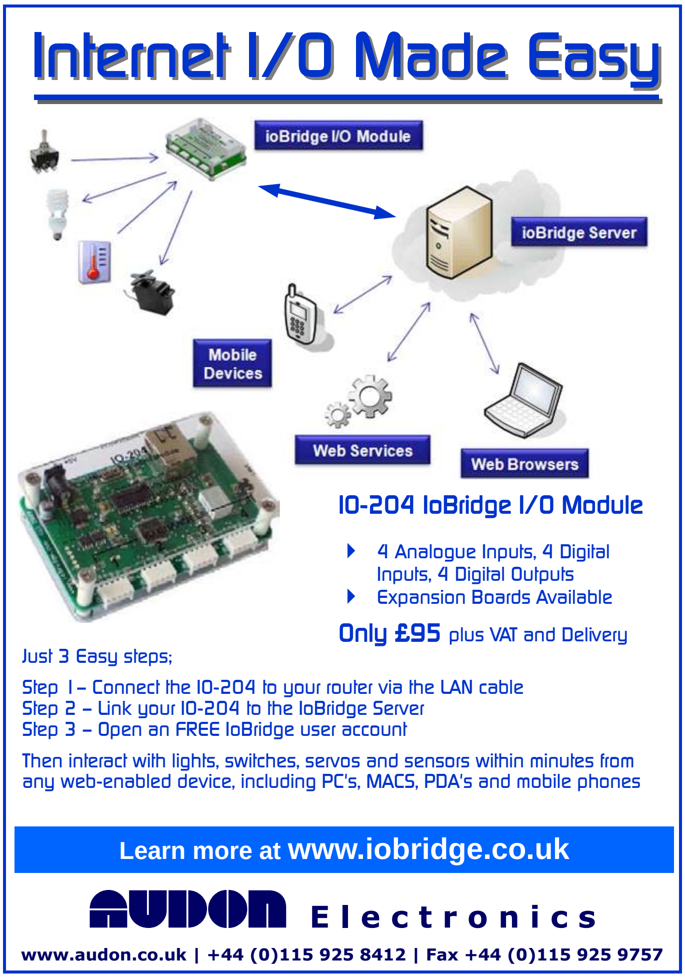
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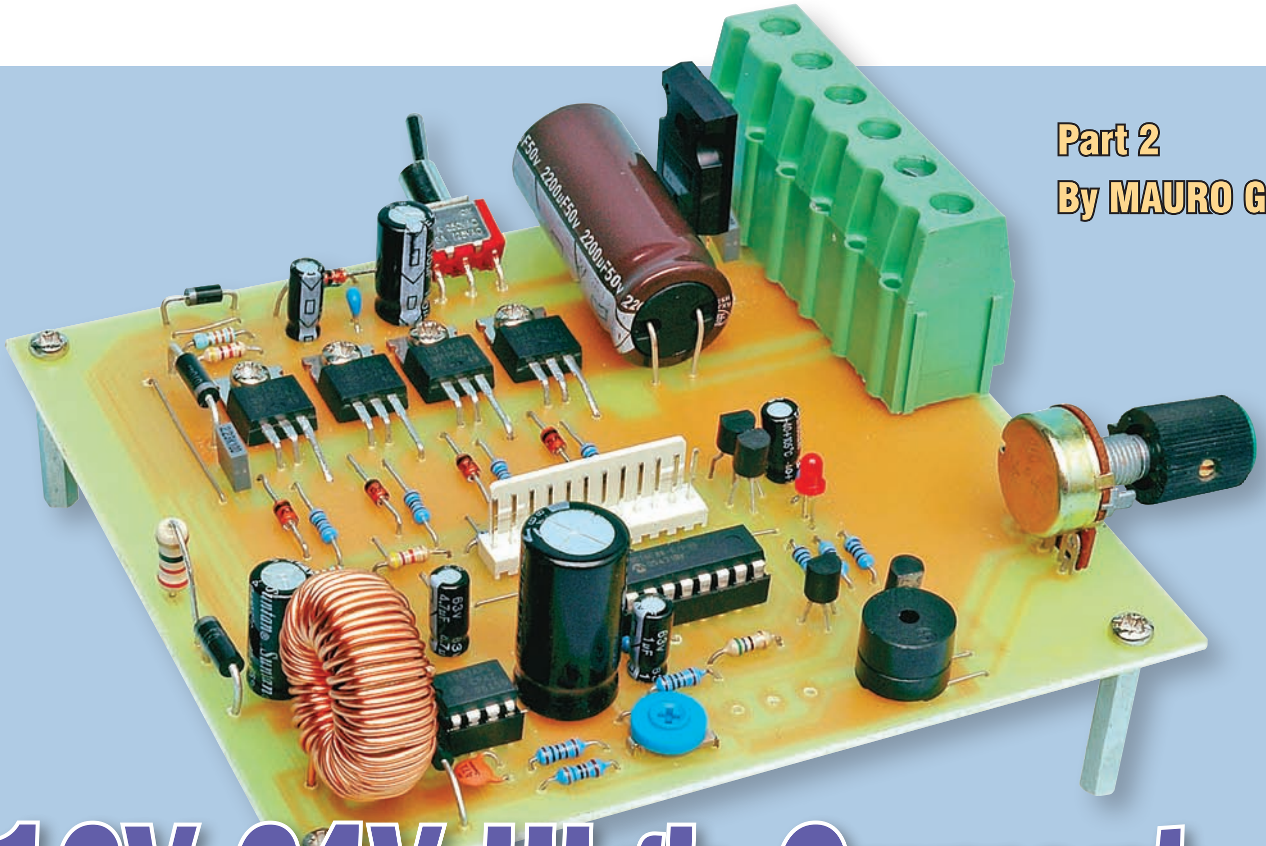


Part 2

By MAURO GRASSI

12V-24V High-Current Motor Speed Controller

Last month, we described the circuit and software features of our High-Current DC Motor Speed Controller. This month, we show you how to build and test it.

THE DC Motor Speed Controller is built on two PC boards: a main board, code 736 (124 × 118mm) and a display board, code 737 (73 × 58mm). The two printed circuit boards are available from the *EPE PCB Service*. These are joined together via a 12-way flat ribbon cable, which plugs into a pin header on the main board.

The main board can be assembled first – see Fig.9. Start by checking the PC board for hairline cracks and for any visible shorts across the copper tracks, especially between the ground plane and any adjacent tracks. In addition, check the hole sizes for the larger hardware items by test fitting these parts into position.

Making a link

That done, begin by installing the 17 wire links. These must go in first, since some of them run underneath some components.

To straighten the link wire, first clamp one end in a vice, then stretch it slightly by pulling on the other end with a pair of pliers. It's then just a matter of cutting the links to length and bending their leads down through 90° to match the holes in the PC board.

The resistors are next on the list. Table 1 shows the resistor colour codes, but you should also check each one using a DMM (digital multimeter) before installing it on the board, as some colours can be difficult to decipher.

Note that resistor R1 should be 1kΩ if the supply voltage will be higher than or equal to 16V. Alternatively, use a 100Ω resistor if the supply voltage is going to be less than 16V. The 22Ω 1W resistor (on the lefthand side of Fig.9) should be mounted 3mm to 4mm proud of the PC board to aid heat dissipation.

Once the resistors are in, install the diodes and the Zener diodes. Take care to ensure that these are all correctly oriented and note that diode D2 (near inductor L1) must be a 1N5819 Schottky type.

Take care also with the Zener diodes. ZD1 to ZD5 are all 16V 1W types, while ZD6 and ZD7 are 33V 5W

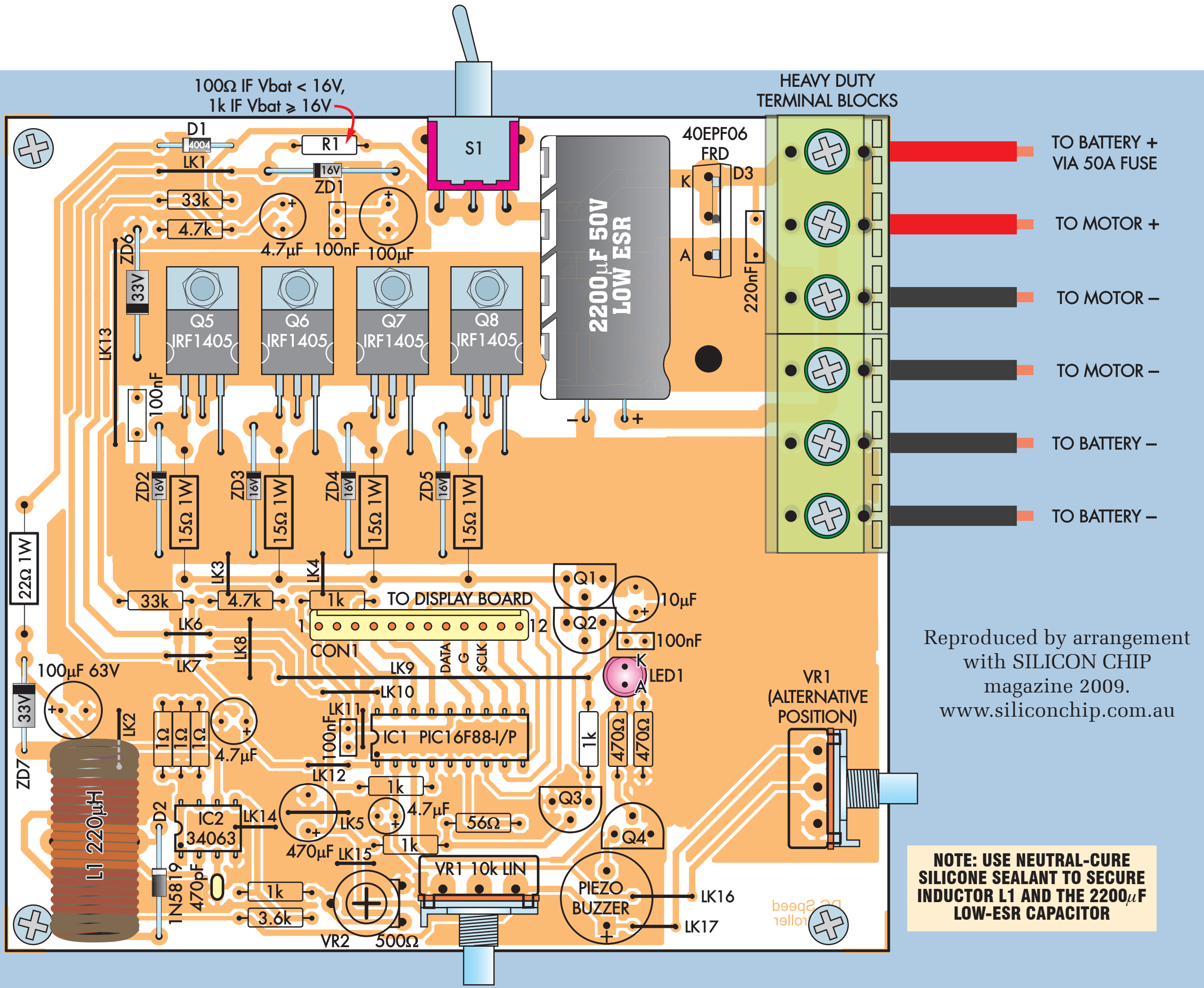


Fig.9: install the parts on the main PC board as shown on this layout diagram, starting with the 17 wire links. The 40EPF06PBF 40A fast recovery diode (D3) is shown in position here but you can also use two MBR20100CT 20A diodes connected in parallel (see Fig.10). Note the alternative positions for VR1.

types. The fast recovery diode (D3) can be left until later, as there are two options for this.

MOSFETs

The next thing to do is to solder in the four power MOSFETs (Q5 to Q8). These all come in a TO-220 package and sit horizontally on the PC board. Note that the source(s) lead of each device extends further than the other two.

Before mounting each device, you will have to first position it on the PC board and bend its leads down through 90° so that they mate with the holes in the board. That done, fasten each device to the PC board using an M3 x 6mm screw and nut *before* soldering its leads.

Do not solder the leads before bolting the metal tab down. If you do, you risk stressing the soldered joints as the screw is tightened, and this could crack the copper or lift the pads.

The next thing to do is to solder in the two IC sockets. Make sure these are oriented correctly as per the component overlay. It is important that you use IC sockets because calibration of the +5V rail is done with microcontroller IC1 out of circuit. This is described later during the setting-up stage.

Now the four bipolar transistors can be soldered in. There are three BC337 *NPN* types (Q2 to Q4) and one BC327 *PNP* type (Q1) – don't get them mixed up. Their leads will only go in one way, and it's just a matter of pushing them down onto the board as far as they will comfortably go before soldering the leads.

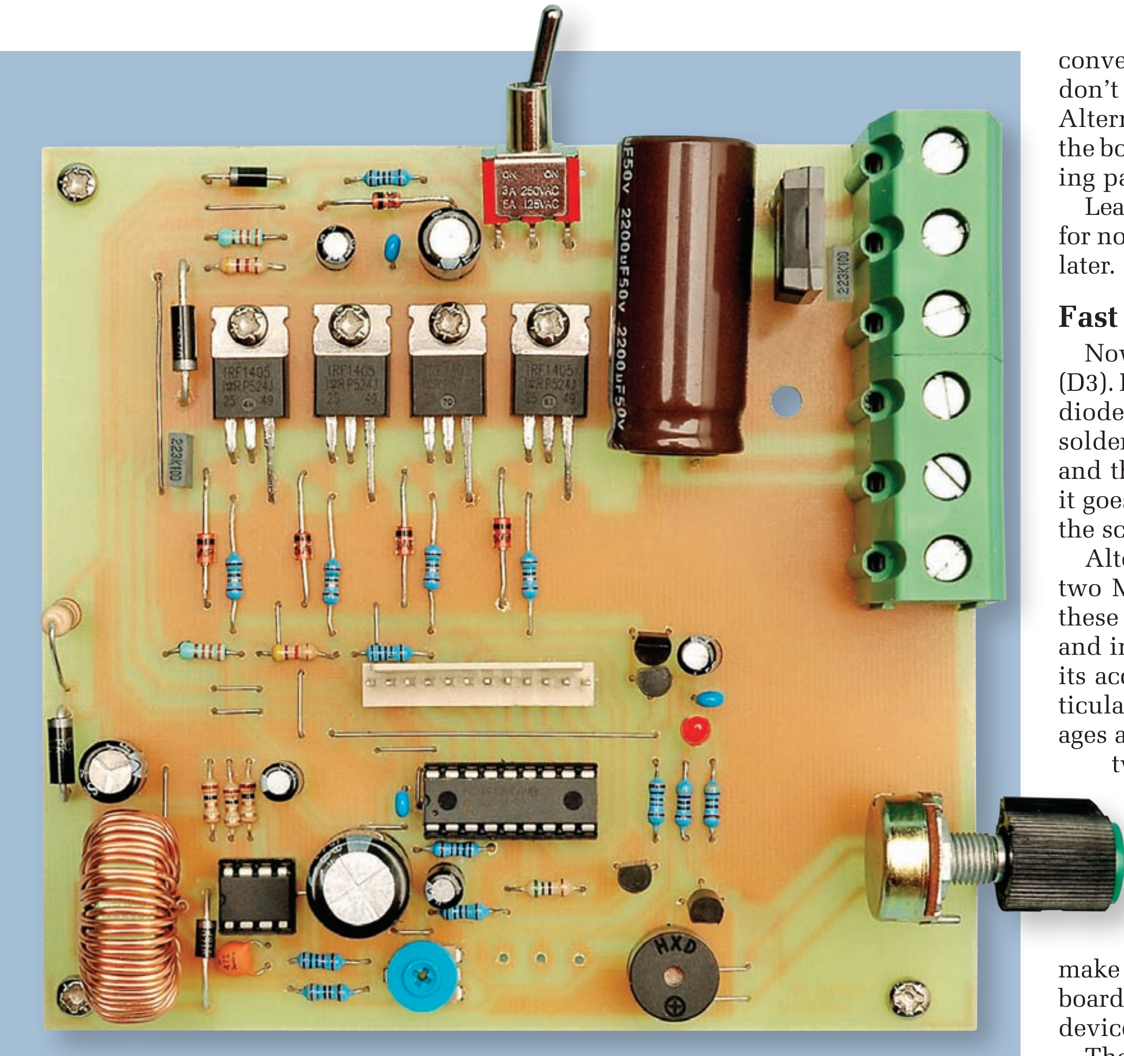
The single 3mm red LED can go in next, again taking care to orient it correctly. Its anode lead is the longer of the two; the cathode can also be identified by a 'flat' on the LED's body.

Follow this with trimpot VR2 and the piezo buzzer. Note that the buzzer must be installed with its positive terminal towards the bottom edge of the board – see Fig.9.

Once these parts are in, you can solder the capacitors in place. The ceramic, monolithic and MKT polyester types can go in either way round, but be sure to orient the electrolytics correctly. The large low-ESR 2200µF capacitor sits horizontally on the PC board, with its leads bent at 90° to go through the holes in the board.

The SPDT horizontal toggle switch (S1) can be soldered in next. Alternatively, this part can be mounted on a panel and connected back to the PC board via flying leads – it all depends on how you intend mounting the board.

The 220µH toroid inductor (L1) sits vertically on the PC board – see photo. Be sure to strip the enamel from its leads and tin them with solder before attempting to solder it in position.



This view shows the fully assembled main board. Note that this prototype board differs slightly from the final version shown in Fig.9.

CON1, the 12-way header, is next on the list. This should be oriented as shown on Fig.9 and the photographs. That done, mount the two heavy-duty 3-way screw terminal blocks. Note that these are dovetailed together to make a 6-way block before mounting them on the board.

Potentiometer VR1 can now be installed. There are two possible locations on the board for this part. Mount it in the position that's the most convenient for your application (but don't install a pot in both positions). Alternatively, it can be mounted off the board and connected to its mounting pads via flying leads.

Leave the two ICs out of their sockets for now. We'll cover their installation later.

Fast recovery diode

Now for the fast recovery diode (D3). If you are using the 40EPF06PBF diode (rated at 40A), then this can be soldered straight in as shown in Fig.9 and the photo at left. Make sure that it goes in with its metal face towards the screw terminal block.

Alternatively, if you are using the two MBR20100CT 20A diodes, then these must be connected in parallel and installed as shown in Fig.10 and its accompanying photos. These particular diodes come in TO-220 packages and each package itself contains two 10A diodes, which are used in parallel.

The middle lead connects to the tab and is the cathode. **This middle lead must be cut off using a small pair of side-cutters,** as the tabs are used to make the cathode connections to the board. The two outer leads of each device are the anode connections.

The procedure for mounting these two diodes is as follows:

1) Drill the hole for the cathode connection on the PC board to 3mm.

2) Lightly tin the copper around the two mounting holes (this is necessary to ensure good contact with the screw heads).

3) Secure the metal tab of the first device to the PC board using an M3 × 12mm screw and nut, with the

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	2	33kΩ	orange orange orange brown	orange orange black red brown
❏	2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❏	1	3.6kΩ	orange blue red brown	orange blue black brown brown
❏	6	1kΩ	brown black red brown	brown black black brown brown
❏	6	470Ω	yellow violet brown brown	yellow violet black black brown
❏	1	100Ω	brown black brown brown	brown black black black brown
❏	1	56Ω	green blue black brown	green blue black gold brown
❏	8	39Ω	orange white black brown	orange white black gold brown
❏	1	22Ω	red red black brown	red red black gold brown
❏	4	15Ω	brown green black brown	brown green black gold brown
❏	3	1Ω	brown black gold gold	brown black black silver brown

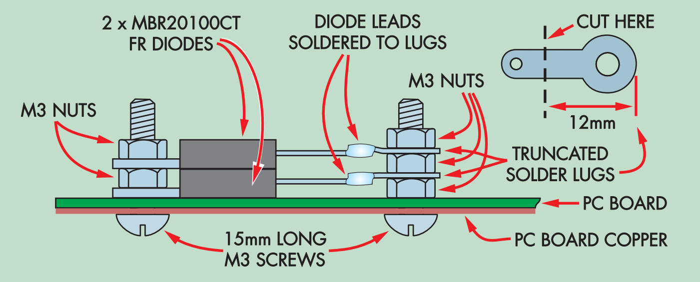
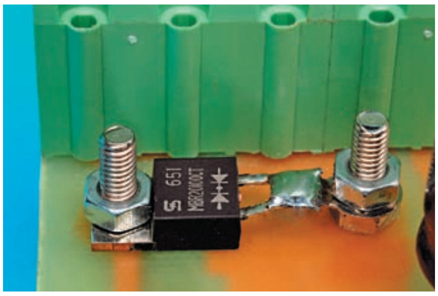
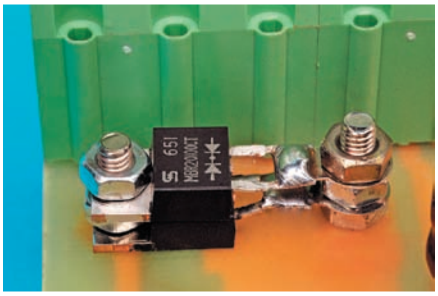


Fig.10: this diagram and the two photos below show how to install the alternative MBR20100CT fast recovery diodes (D3).



In this photo, the first diode has been fastened into position and its two outer leads soldered to the solder lug.



The second diode is then mounted in position and its outer leads soldered to the top solder lug.

screw passing up from the underside of the board. Tighten the nut down firmly.

4) Install an M3 × 12mm screw through the hole at the anode end of the diodes, secure it with a nut, then fit a solder lug and secure it with a second nut. Again, make sure the nuts are done up tightly.

5) Solder the two outer leads of this first device to the solder lug, then fit another solder lug and nut.

6) Secure the tab of the second device in position and solder its outer leads to the top solder lug.

Building the display board

The display board is optional, but will be useful in many applications. If you decide not to build it, you will not be able to change the settings, and the default values will have to be used. You will also have no way of knowing what percentage of full speed the motor is running at.

As before, check the board for defects. In particular, check for shorts between copper tracks or between the ground plane and any adjacent tracks.

Start the assembly by installing the 23 wire links. Some of these sit under the 7-segment LED displays, so make sure these links sit flat against the PC board. Don't forget the short links immediately to the left of CON2 and at bottom right.

The resistors can go in next, followed by the 100nF capacitor and the four transistors (Q9 to Q12). If you are using an IC socket for IC3, then this can also now go in. Install it with its notched end positioned as indicated on the diagram, then install IC3 (74HC595).

Alternatively, IC3 can be directly soldered to the PC board. Be sure to install the IC with the correct orientation – ie, its notched end goes towards CON2.

Finally, complete the display board assembly by installing a 12-way pin header (this part is optional), the two pushbutton switches and the four 7-segment displays. Be sure to orient the displays with the decimal points at bottom right.

Similarly, make sure that the pushbutton switches are correctly oriented. As shown in Fig.11, they must each be installed with the flat side towards the displays.

Connecting the boards

Once the board assemblies are complete, make up a 12-way ribbon cable to connect the two boards together. This should be terminated at either end to a 12-way header plug. Be sure to arrange this cable so that pin 1 of the header of the main board connects to pin 1 of the header of the display board and so on.

Set-up

Once you have completed the construction, the next step is to go through the setting up procedure. You also need to adjust trimpot VR2 on the main board, so that the output from the MC30463 IC (IC2) sits at exactly +5V (this rail must be at exactly +5V to ensure that voltage measurements made by the microcontroller are accurate).

The set-up procedure is as follows:

1) Check that the two ICs on the main board are out of their sockets and that toggle switch S1 is in the OFF position (ie, the switch should be in the opposite position to that shown Fig.9).

2) Connect a 12V to 24V DC supply to the screw terminal blocks (check the supply voltage before you do this).

Note that if you are connecting the supply leads directly to a battery, there could be a spark when you first connect power due to the low-ESR 2200µF bypass capacitor across the supply. For this reason, connect the supply leads to the battery first, then to the terminal blocks, as it's never a good idea to generate a spark near a battery.

As noted previously, resistor R1 should be 1kΩ if you are using a supply greater than or equal to 16V. Alternatively, R1 should be 100Ω if you are using a supply less than 16V.

3) Apply power to the circuit by toggling S1 to ON.

4) Check the voltage on D1's cathode. It should be about 0.6V less than the supply voltage.

5) Check the voltage on ZD1's cathode. This should be very close to +16V if you are using a power supply that's greater than 16V. Alternatively, it should sit between +12V and +16V if you are using a 12-16V power supply.

6) If these voltages are OK, switch off and install the MC34063 switchmode IC (IC2) into its socket. Make sure that the notch on the IC matches the notch on the socket – ie, the notch must face towards inductor L1.

7) Apply power and check the voltage at pin 1 of the 12-way header on the main board. This is the +5V rail, but it may not yet be at exactly +5V (the exact voltage depends on the setting of trimpot VR2).

8) Adjust VR2 until the voltage on pin 1 of the header is exactly +5V.

9) Assuming that the above voltage is now correctly set, switch off and insert microcontroller IC1 into its

Questions, Problems and Answers

Question: is the display board really optional?
Answer: yes, the display board is optional and the DC Motor Speed Controller will function without it. However, the display board is necessary if you want to change the settings of the battery alarm, the audible cues and the frequency of the PWM, as well as to view the current speed of the motor and the values of the settings.

We therefore recommend that you build the display board as well, even if you use it to change the settings only once. If this board is subsequently disconnected, the speed controller will still work and will use the last settings stored in the microcontroller's non-volatile memory.

Problem: when using the display board, not all digits light up. What should I do?
Answer: check the 12-way cable and the pin header connections. Check that all 12 connections are good.

Problem: the voltage at the cathode of ZD1 is nowhere near 12-16V (it should be 16V if the supply voltage is 16V or greater).
Answer: check the orientation of ZD1 and check for incorrect power supply connections.

Problem: the power supply voltage does not appear on the cathode of D1.
Answer: in normal operation, D1's cathode should sit about 0.6V below the supply voltage. This cathode should not exceed 40V at any time, or damage may occur to the switchmode IC and to the microcontroller. ZD7, a 33V 5W Zener diode, is there to protect against high voltages on this rail.

Problem: some components are getting quite hot.
Answer: in normal operation, all components should run cool except for the fast recovery diode (D3), the four power MOSFETs Q5 to Q8 (especially if high currents are being switched) and possibly Zener diodes ZD6 and ZD7, although the latter should not get too hot. If they do, it could mean that the supply lead inductance is causing high transient voltages on the supply rail.

Normally, the low-ESR 2200µF capacitor should filter these out, but if you do strike problems, try minimising the length of the power supply connecting leads (as well as those to the motor, if possible). You should also twist the positive and negative power supply leads together in order to cancel any magnetic fields induced by high currents.

Problem: the speed controller does not respond to the pushbutton switches on the display board.
Answer: this could be caused by the pushbuttons being incorrectly oriented on the display board. Make sure the two pushbuttons are installed with their flat sides as indicated on the components layout diagram (Fig.10).

Problem: LED1 (red) lights but there is no beep from the piezo buzzer. Alternatively, there is a beep from the piezo buzzer but the LED does not light.
Answer: either the LED or the buzzer is incorrectly oriented.

socket. Make sure that its notched end goes towards link LK11.

10) Plug the display board into the 12-way header and apply power. If everything is working correctly (and assuming a motor isn't connected), the 4-digit display should immediately read 'P00.0', indicating the current speed.
11) If it all works correctly, skip the following troubleshooting section and go straight to the software initialisation procedure.

Troubleshooting

If you strike problems, the first thing to do is go back and check the board for any missed or bad solder joints. Check also that there are no shorts between tracks or between the ground plane and any adjacent tracks.

If these checks don't reveal the problem, we suggest that you go through the following checklist:

1) Check that all 17 links are installed on the PC board. A missing link could mean that parts of the ground plane are floating and this will lead to improper operation!
2) Check that all polarised components, including the diodes, Zener diodes, electrolytic capacitors and ICs are correctly oriented as per the component overlay.
3) Check that you have used the correct value for R1, depending on your input supply voltage.
4) Make sure that the four transistors on the main board are the correct types. Q2 to Q4 are all BC337s but Q1 is a BC327 type.
5) Make sure that the input voltage connections to the 6-way terminal block are correct.

We have also assembled a list of likely questions and answers that may help you troubleshoot the DC Motor Speed Controller if it is not operating as expected – see accompanying panel.

Software initialisation

If your boards are working, it is now time to initialise the software settings before connecting a motor. To do this, you must have the display board connected to the control board.

Note that more detailed user instructions for the DC Motor Speed Controller appeared in Part 1 last month. This section simply explains how to change the battery level alarm and the frequency of the PWM before you use the unit for the first time. These settings will be retained in non-volatile memory.

When the microcontroller begins executing the firmware (from a power-on reset) you should be taken straight to the main menu. This will indicate the percentage of full speed that the motor is currently running at. Without a motor connected, it should read 'P00.0'.

From here, press 'short R' twice (see Part 1) to arrive at the battery level alarm menu. This menu shows an 'A' followed by a 3-digit voltage value. which indicates the voltage level below which the low battery alarm will sound.

In this menu, press 'long L' to set the level using potentiometer VR1. The 'A' should start flashing and you should then be able to vary the pot to change the level. Once you are happy with the current level, press 'short L'

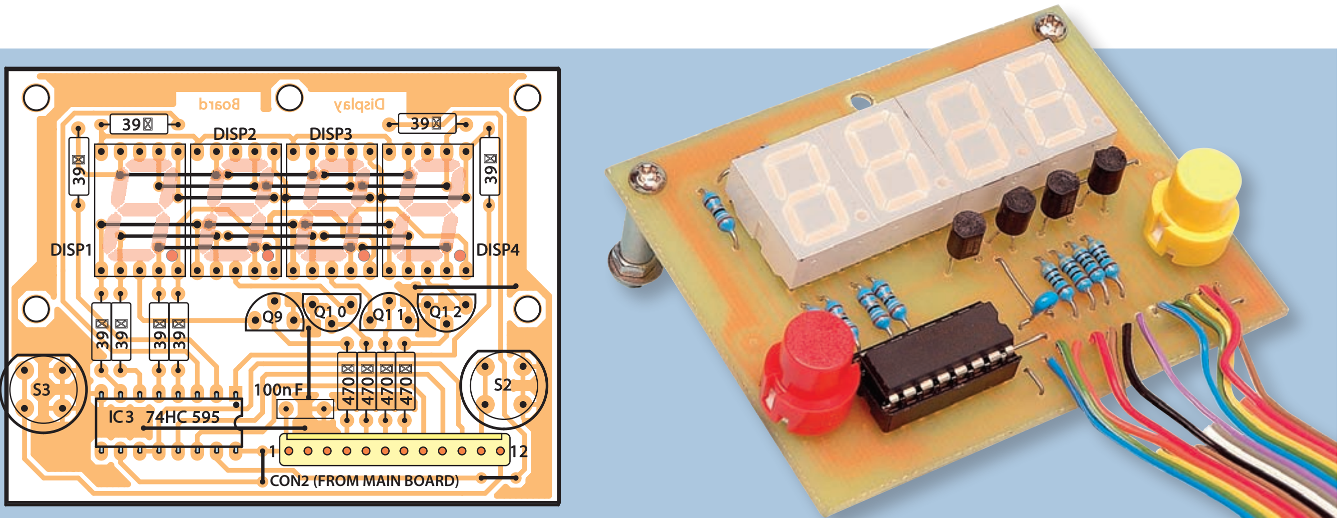


Fig.11: here's how to assemble the optional display board. Make sure all parts, including the switches, are correctly oriented.

to update the setting and return to the main menu.

Next, press 'short R' three times to arrive at the frequency menu. This will show an 'F' followed by a 3-digit frequency in kilohertz.

Once you are in this menu, press 'long L' and set the frequency of the PWM (pulse width modulation) using VR1. The 'F' should flash while you are setting the frequency. In practice, the frequency can be set to one of 256 values between 488Hz and 7812Hz.

Once you have set the desired frequency, press 'short L' to store the setting and return to the main menu.

That's it! For more detailed instructions on the other software modes, refer back to Part 1, last month.

Connecting the motor

Once you have verified that the DC Motor Speed Controller is working correctly, you can connect a motor. This should be connected with its positive terminal to the second terminal block from the top, while its negative terminal can go to either the third or fourth terminal from the top.

Note that all supply and motor connections to the terminal block should be run using heavy-duty 56A wire.

The top terminal block is used to terminate the positive supply lead from the battery. **This lead should connect via the 50A in-line fuse.** Either of the bottom two terminals can be used for the negative battery lead (ie, one is left unused).

Your DC Motor Speed Controller is now ready for action. ***EPE***

TEACH-IN 2010

LADDER LOGIC PROGRAMMING FOR THE PIC MICRO

Part 3: Timers and Shift Registers

By Walter Ditch

PART three of this series on ladder logic (PLC-style) programming for the PIC micro continues the tour of sequential logic by looking at timers and shift registers. This builds upon previous coverage of input/output commands, oscillators, combinational logic and self-latching circuits, allowing an increasingly wide variety of systems to be developed.

Timers often prove useful when building ladder-logic-based systems, making it easy to add time delays and timed outputs. For example, delaying an action for a specific interval (an on-delay timer) or performing a task for a given period of time (a pulsed timer output). Timer applications considered here will include an automatic alarm timer and a switch de-bounce circuit.

Shift registers

Shift registers are also valuable, allowing a binary pattern held in a register to be shifted to the left or right. A typical shift register application would be the creation of a moving light display, although they have many other uses.

The present article will also delve into the PLC software's use of internal memory (registers). This knowledge may be required when writing programs, and often proves useful when debugging ladder logic software applications. For example, the internal state of a timer or counter is normally only visible to the programmer as a single finished/not finished status bit, but the internal count value is also available as a byte value – if you know where to look.

In passing, a few of the PLC software's byte processing commands will be introduced, these being used to simplify the coding of some of the example programs. A byte I/O command, for example, will be used to display the internal content of a shift register on a chosen output port. We'll also make use of a byte comparison command to simplify the coding of a rudimentary 'KnightRider' style display.

Coverage of the sequential logic capabilities of the PLC software will continue next month with the introduction of counters and pulse-width-modulated (PWM) signals.

As discussed previously, all program listings for this article are available from the Library > Project Code section of the *Everyday Practical Electronics* website (**www.epemag.com**). It is suggested that you copy the files from each part of the series into a single folder on your computer, which will ensure you have easy access to the PLC header files supplied with Part 1. You should also have installed the MPLAB IDE software, and of course you will need a suitable PIC development board or simulation software in order to actually try out your programs. Please see earlier articles for further details of the development process, supported PIC microcontrollers, and associated hardware and software.

Also, remember that the example programs may easily be converted to run on any of the supported PIC microcontrollers. To do this, first modify the header file reference, and then change input and output port assignments to suit those available with the chosen microcontroller.

Using low speed timers

So far, most of the programs considered have either produced an output if a specific condition is true at that instant (combinational logic), or have latched a momentary input signal (simple sequential logic). This has allowed the development of some useful applications, including the simple alarm circuit of Listing 2.9, as seen in Part 2.

A useful addition to this circuit would be the use of a timer to cancel the alarm after a period of inactivity. To that end, we'll first see how to configure a low speed timer, and then use a timer with a simple alarm circuit.

The PLC software provides up to 16 built-in timers, eight of which are 'low speed', with the remainder

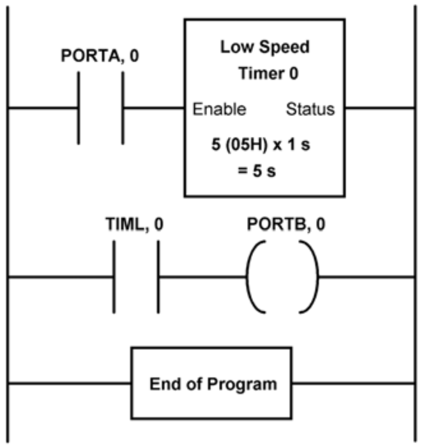


Fig.3.1. Using a low-speed timer to give a five-second delay

being 'high speed'. For time delays in the range 4ms to 1 second, you can use a high-speed timer, while longer delays, in the range 1 to 255 seconds, may be achieved with a low-speed timer. (Even longer delays are possible by using 'custom timer' circuits, as will be seen in Part 4.)

The creation of a simple time delay using a low-speed timer is shown in the ladder diagram of Fig.3.1 above.

This example provides a five-second time delay (an on-delay timer), with the timer's output bit TIML bit 0, going high five seconds after the input bit PORTA bit 0. An equivalent program, based on the PIC16F88 microcontroller, is given in Listing 3.1

The first argument supplied to the low-speed timer command 'timl' is the timer number, which is in the range 0 to 7. The corresponding bit of register TIML (0-7) holds the status bit for for the selected low-speed timer. (Thus, TIML bit 0 holds the status bit for low-speed timer 0, and so on). Recall also from Part 1, that PLC command names are lower case (timl), while register names are upper case (TIML).

Begin counting

An enable signal derived from Port A bit 0 causes the timer to begin counting. The timer is preconfigured with a final value in the range of 1 to 255, which allows time delays of up to 255 seconds to be achieved. The timer's status bit becomes set after the time period has expired. Removing the enable bit resets the timer to its initial value and clears the output bit of the timer. Thus, the timer has three possible states.

1. Reset (enable input = 0, status output = 0)
2. Timer in progress (enable input = 1, status output = 0)
3. Timer finished (enable = 1, status = 1)

An important difference between a timer and a latch is that the enable input needs to be continuously applied, in order to 'enable' the timer to count. If a momentary enable input is required, then this should be used to first set a latch, with the latched output enabling the timer. A typical example would be the addition of a timeout feature to the alarm circuit previously considered in Part 2, Listing 2.9. A possible modified program is given in Listing 3.2, based on the PIC16F627/627A microcontroller.

Considering the program operation, it can be seen that Port A bits 0-2 act as three separate input sensors. The combined sensor status is stored temporarily in auxiliary relay

```
include "16F88_L.PLC"   ; Defines PLC instructions
                        ; (Low voltage programming enabled)

ld      PORTA, 0        ; Read Enable input
timl    0, 05H          ; Low Speed Timer 0, final value = 5 seconds

ld      TIML, 0         ; Read low speed timer 0 status bit
out     PORTB, 0        ; Output timer 0 status to Port B bit 1

endp                    ; Marks end of PLC program
```

Listing 3.1. Creating a five second delay using a low-speed timer (Lst3_1.asm)

```
                          ; I/O Schedule
                          ; Sensors = Port A bits 0-2 (1 = active)
                          ; Armed/Reset = Port A bit 3
                          ; (1 = armed / 0 = reset)
                          ; Output = Port B bit 0 (1 = triggered)

include "16F627.PLC"      ; Defines PLC instructions

ld      PORTA, 0          ; Load Sensor 1
or      PORTA, 1          ; Or with Sensor 2
or      PORTA, 2          ; Or with Sensor 3
out     AUX0, 0           ; Output Alarm Sensor Status to AUX0, 0

ld      AUX0, 0           ; Read Alarm Sensor status (Set input)
latch   AUX0, 1, AUX0, 2  ; Latched Alarm Status to AUX0 bit 1
                          ; Reset = AUX0 bit 2

ld      AUX0, 1           ; Read Latched Alarm status
timl    0, 0x05           ; Low Speed Timer 0 with 5 second timeout

ld      TIML, 0           ; Read Alarm Timeout (1 = timeout reached)
and_not AUX0, 0           ; Don't reset if active (* optional *)
or_not  PORTA, 3          ; OR with inverted Arm/Disarm input
                          ; (0 = disabled)
out     AUX0, 2           ; Output Reset Alarm signal

ld      AUX0, 1           ; Read Latched Alarm signal
and_not TIML, 0           ; Disable if timed out (* optional *)
out     PORTB, 0          ; Alarm output to buzzer / indicator

endp                      ; Marks end of PLC program
```

Listing 3.2. Adding a timeout to a simple alarm (Lst3_2.asm)

AUX0 bit 0, which in turn is used as the Set input to a latch circuit. The Q output of the latch is sent to bit 1 of register AUX0, while bit 2 of the same register provides the Reset input signal to the latch.

Next, the latch output becomes the input to a five-second timer, with the timer output being used to reset the latch, hence cancelling the alarm (five seconds is fine for testing purposes, but a longer time delay would, of course, be used in practice). Finally, an audible or visible alarm output is generated by copying the latch output state to an appropriate output port bit (Port B bit 0 in this example).

Notice that two of the program lines are marked as 'optional' in the comments at the right. Try adding and removing these lines to see the different behaviours of the alarm, following a timeout. With both lines removed, the alarm will automatically reset after a time-out, thus re-enabling the alarm (suitable for a retail exit barrier alarm, for example).

However, this behaviour might cause annoyance in a residential burglar alarm, where a faulty sensor could cause the alarm to be re-triggered repeatedly after each time-out. In the latter case, adding the two optional lines has the effect of first preventing a reset while a sensor remains active, and second, cancelling the output if the alarm has timed out.

High-speed timer applications

Operation of the eight high-speed timers is almost identical to that already seen with low-speed timers, but with three significant differences, as given below.

1. The 'timh' (high-speed timer) command is used in place of 'timl'. As with low-speed timers, remaining command arguments are the timer number (0 to 7) followed by the final timer value in the range 1 to 255.

2. The high speed timer's status bit is available from the appropriate bit of the TIMH register, with a value of '1' indicating that the timer is finished. (Recall that low speed timers use the TIML register.)

3. The timer's internal count value increments once every four milliseconds, giving possible time delays from 4ms to approximately one second.

Note: As you may have already guessed, low-speed and high-speed timers are actually implemented as *counters*, with the input to the counter being derived from an appropriate oscillator bit. This knowledge will prove useful in Part 4, when we build a custom timer.

On the bounce

One problem often encountered when dealing with input switches is that of contact bounce. This mechanical effect is analogous to dropping a tennis ball onto a hard surface, and then watching it bounce several times before settling.

Exactly the same effect occurs when the mechanical contacts of a switch are closed, but with the time for the contacts to settle being measured in milliseconds. Contact bounce can be particularly troublesome where an input switch is directly connected to a counter, with a single switch press causing the counter to increment multiple times.

A useful high speed timer application would be a switch debounce circuit, with a 10 to 20ms on-delay timer being typically suitable. The output of the on-delay timer may then be used as the debounced input signal. Listing 3.3 gives a simple example, written this time for the PIC16F887 microcontroller, and making use of a repeating input waveform being derived from an oscillator bit.

Pulsed outputs

The timers considered so far have all been of the 'on-delay' variety. It is also possible to produce a pulse output by making a relatively small modification to the program. The trick in this case is to realise that during the timer period the enable input will be high, while at the same time the status bit will be

```
include "16F887.PLC"    ; Defines PLC instructions

ld      OSCH, 7         ; Read a 15.26 HZ waveform (T = 65.54 ms)
out     PORTD, 0        ; Send waveform to Port D bit 0

ld      PORTD, 0        ; Read Port D bit 0
                        ; (15.26 Hz waveform = Enable input)
timh    0, 03H          ; High Speed Timer 0, final value = 3
                        ; (T = 3 x 4 ms = 12 ms)

ld      TIMH, 0         ; Read timer status bit
out     PORTD, 1        ; Output debounced signal

endp                    ; Marks end of PLC program
```

Listing 3.3. A switch debounce circuit based on a high speed timer (Lst3_3.asm)

```
include "16F887.PLC"    ; Defines PLC instructions

ld      OSCH, 7         ; Read a 15.26 HZ waveform (T = 65.54 ms)
out     PORTD, 0        ; Send waveform to Port D bit 0

ld      PORTD, 0        ; Read Port D bit 0
                        ; (15.26 Hz waveform = Enable input)
timh    0, 03H          ; High Speed Timer 0, final value = 3
                        ; (T = 3 x 4 ms = 12 ms)

ld      TIMH, 0         ; Load timer status bit
out     PORTD, 1        ; Output debounced (on-delay) signal

ld      OSCH, 7         ; Read high speed timer Enable input
and_not TIMH, 0         ; AND with inverted Status bit
out     PORTD, 2        ; Output pulse waveform to Port D bit 2

endp                    ; Marks end of PLC program
```

Listing 3.4. Creation of on-delay and pulse output waveforms (Lst3_4.asm)

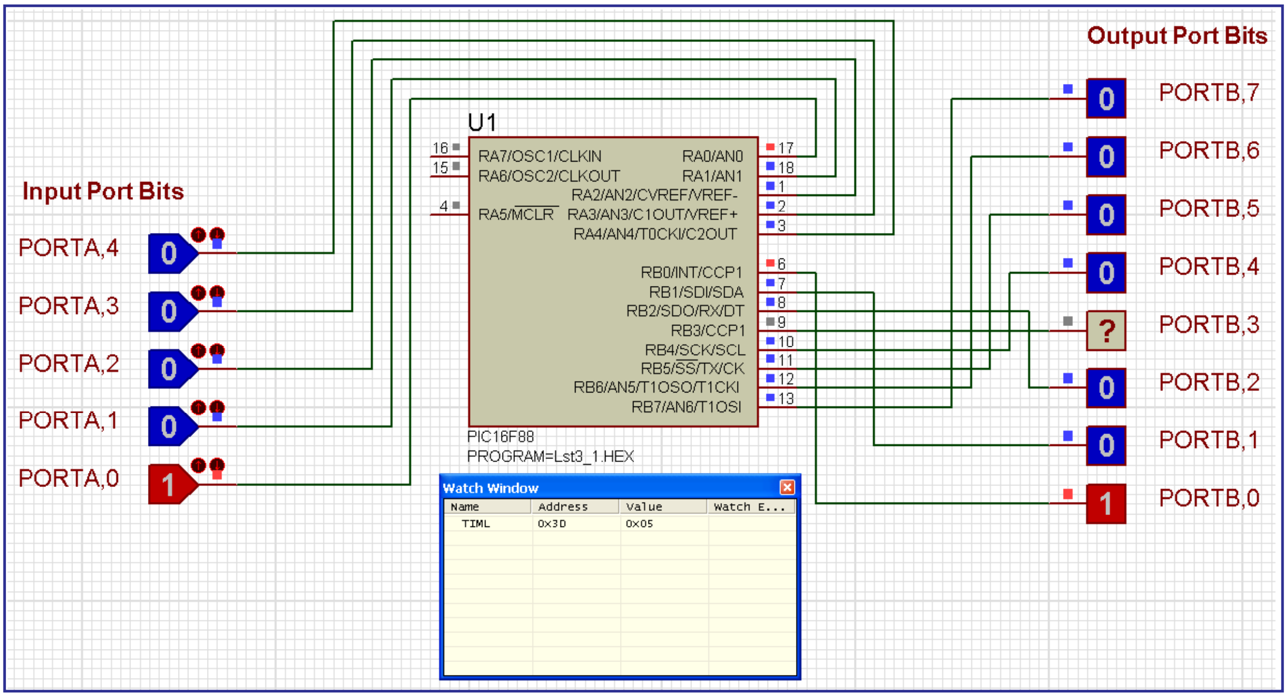


Fig.3.3. Debugging with the aid of the Watch window in Proteus VSM software

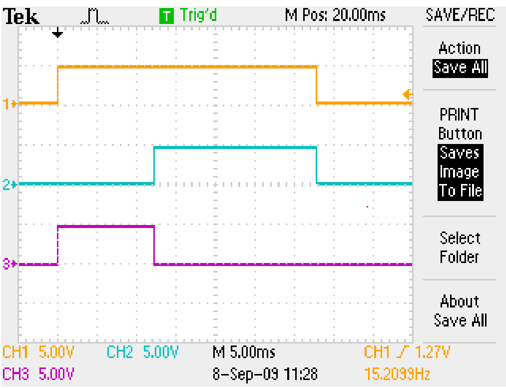


Fig. 3.2.Output waveforms viewed using an oscilloscope

low. Listing 3.4 shows the creation of both on-delay and pulsed outputs, once again using a repeating oscillator bit as the input.

Resulting waveforms are shown in Fig.3.2, which was produced with the program of Listing 3.4 running on a PICkit 2 Debug Express development board, and viewed using a Tektronix TDS2004B four-channel digital storage oscilloscope.

In this case, the original waveform is shown in orange, while the blue and magenta traces give the on-delay and pulse outputs respectively. Notice that, based on the timebase of 5ms per division, the pulse width is approximately 12ms, which is in agreement with the delay value selected in Listing 3.4.

Use of internal storage and debugging programs

An understanding of the PLC software's use of internal memory is useful when debugging programs, and may in some cases be required when actually writing programs (as will be seen in the next section).

The PLC software uses a variety of PIC registers to hold its internal state, some of which have already been introduced. Each of these registers (around 100 in total) holds a single byte of data. Addresses associated with these registers, and others yet to be introduced, can be viewed by opening any of the PLC header files in a text editor. Listing 3.5 shows a short (and slightly simplified) extract.

Considering the timers discussed in the previous section, each of the low and high frequency timers uses a dedicated register to hold its internal count value, in addition to the finished/not finished status bits held in the TIMH and TIML registers. Under normal circumstances, the internal count values are not directly visible to the programmer. However, it may be useful to view these registers when debugging programs – after, of course, finding the appropriate addresses from the header file.

Available debugging options related to the display of internal registers include:

1. Adding one or more 'watch' commands in an Integrated Development

```
OSCH    EQU    H'01'    ; High frequency oscillator register

AUX0    EQU    H'20'    ; Internal relay outputs
AUX1    EQU    H'21'
AUX2    EQU    H'22'
AUX3    EQU    H'23'
AUX4    EQU    H'24'
AUX5    EQU    H'25'
AUX6    EQU    H'26'
AUX7    EQU    H'27'    ; (8 bytes x 8 bits = 64 internal relays)

OSCL    EQU    H'28'    ; Low frequency oscillator register
```

Listing 3.5. A small selection of internal memory used by the PLC software

Syntax	Function
puti BYTE, REGISTER	Loads an immediate byte value into a destination register (puti = *put immediate*).
putr REG1, REG2	Copies the content of a source register to a destination register, leaving the source unaltered (putr = *put register*).

Table 3.1. Available byte transfer commands

```
        include "16F627.PLC"    ; Defines PLC instructions

        puti    0x0F, AUX0      ; Load 0x0F (hex.) into register AUX0
        putr    AUX0, PORTB     ; Copy AUX0 register to Port B

        endp                    ; Marks end of PLC program
```

Listing 3.6. Transferring data bytes between registers (Lst3_6.asm)

Environment (IDE), in order to view the state of internal registers as the program is running (which is generally the preferred method, if available).

2. Using a byte transfer command to temporarily copy an internal register to an output port, allowing its state to be directly viewed on externally connected LEDs or 7-segment displays.

Byte transfer

For example, to add a watch statement when using Proteus VSM software, with the simulation either running or paused, select the Watch Window option from the Debug pull-down menu. Next, right-click on the displayed Watch window and select the Add Items (By Address) option from the context menu.

Enter the name of the register to be observed, its address (with the prefix '0X' indicating a hexadecimal number) and the required display format. Fig.3.3 shows the addition of a watch statement in order to view the internal count associated with low-speed timer 0 (register TIML0), this being suitable for debugging the program of Listing 3.1.

Should a full-blown IDE not be available, then an alternative would be to use a byte copy command to copy the register of interest to an unused output port. Byte I/O commands may be used either to load an immediate (program-specified) byte value into a register, or to copy a byte value from one register to another. Table 3.1 gives the syntax and operation of the two available variants.

The use of byte transfer commands is not mandatory, but is certainly much quicker than the repetitive copying of individual bits with 'ld' and 'out' commands. The example of Listing 3.6 illustrates just how easy it is to load a byte value into a temporary register and then copy the result to an output port.

Notice that the above listing uses the '0X' prefix to indicate a number in hexadecimal format. (This format was also seen when adding a watch statement in Proteus VSM, in Fig.3.3 and the associated text.) The MPLAB IDE assembler (MPASM) accepts numeric data in a variety of other number bases (radixes) and formats, including binary, octal, decimal (or denary) and hexadecimal.

A few of the accepted formats include b'01010101' (binary), o'067' (octal), d'255' (decimal) and h'ff' (hexadecimal), with the first character being accepted in either upper or lower case. One which is most suitable depends on your personal preference, together with the application. See the MPASM assembler's help file for a full list of supported number formats.

We'll revisit the use of byte transfer instructions in the next section, where they will be used with shift register programs to make the result visble on a bank of output LEDs

Shift registers

Shift registers are useful circuits, which have many potential uses, including the creation of moving light display patterns, sequencers, or even the temporary storage of pass/fail information related to components passing along a production line. The internal structure of a simple shift register is shown in Fig.3.4.

This simple shift register holds a number of data bits inside an internal working register. Each clock pulse causes the data to be shifted one place to the right, in the direction of the arrows. New data is shifted in at the left hand side (supplied by an external source), while old data is shifted out at the right (being either discarded or used elsewhere). Although this simple shift register is unidirectional, a useful additional feature would be a Direction input, allowing data to be shifted either to the left or right, under program control.

Up to eight shift registers are available in the PLC software (numbered 0 to 7), each of which has an 8-bit working register. These may be used singly, or may be linked together 'end to end' in multiples of 8-bits, allowing a composite shift register with up to 64-bits to be created.

Each shift register has an 'implicit' data input, provided by the result of the previous instruction, followed by Clock, Reset and Direction inputs, each of which are specified using a port name and a port-bit. A dedicated 8-bit working register holds the internal state of each shift register, and this value may be copied to an output port, if required. The syntax of the shift register command has the following general form:

```
shift NUMBER[0-7],
CLOCK_REG, CLOCK_BIT[0-7],
RESET_REG, RESET_BIT[0-7],
DIRECTION_REG, DIRECTION_
  BIT[0-7]
```

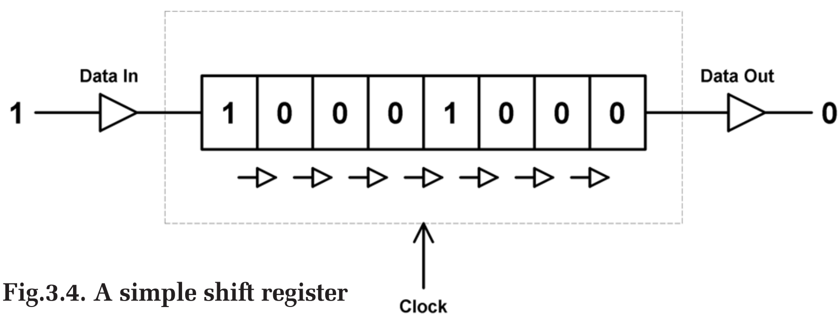


Fig.3.4. A simple shift register

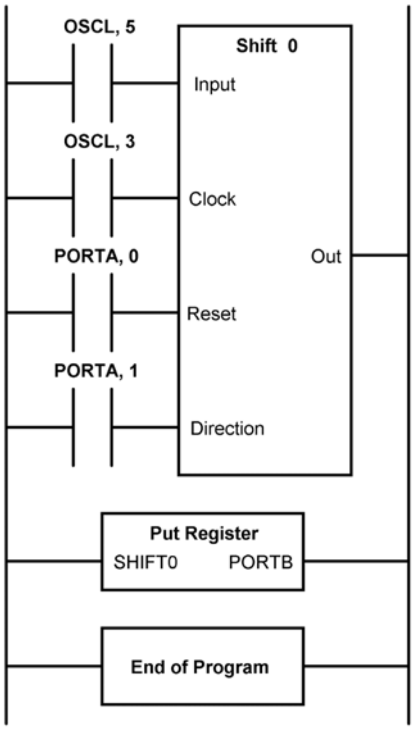


Fig.3.5. Ladder diagram for a simple shift register program

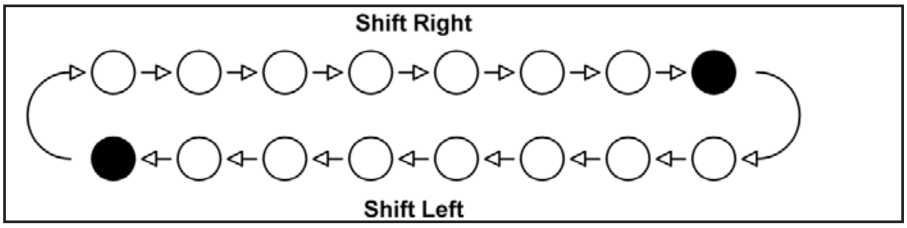


Fig.3.6. Animating a simple 'KnightRider' display

A simple shift register application is shown by the ladder diagram of Fig.3.5.

The example program uses a 0.25Hz input signal as the data input to a shift register, with the clock being driven by a 1Hz signal. This creates an alternating pattern of two ones, followed by two zeros, since the clock frequency is four times faster than that of the data input.

A visible output is produced by the 'putr' command, which copies the shift register's output register (SHIFT0) across to Port B. The equivalent program is given in Listing 3.7, in this case based on the PIC16F627 microcontroller.

It is also straightforward to link or 'chain' multiple shift registers, as shown in the example of Listing 3.8, this time written for the PIC16F887 microcontroller.

The trick in this case is to understand exactly how data enters and exits each shift register. As already seen, the data input to a shift register is supplied by the result of the previous command. Similarly, data shifted out of one shift register becomes available to the next command (or is discarded if unused). Thus, all that is necessary to cascade multiple shift registers is to write each shift register command on successive lines, so the output of one shift register then becomes the input to the next.

Use of one or more Watch statements is a useful strategy when debugging programs containing multiple shift registers, as long as a suitably equipped IDE is available. You may then create a watch statement for each shift register and observe data rippling through from one working register to the next. (Note in relation to Listing 3.8 that registers SHIFT0-SHIFT2 make use of memory locations 0x47-0x49.)

Light chaser

The final example for this part of the series involves repeatedly moving a single illuminated LED to the left and right of an output port, which is the basis of the well known KnightRider display (from the classic TV series of the same name). This is shown graphically in Fig.3.6.

A latch is used to control the direction of the shift register, with the latch being automatically set and reset as the illuminated bit 'bounces' off each side of the output register. Changing the direction of the shift register is achieved in software by linking the latch's Q output to the

```
include "16F627.PLC"          ; Defines PLC instructions

ld      OSCL, 5               ; Read OSCL bit 5 (Data input)
shift   0, OSCL, 3, PORTA, 0, PORTA, 1
                              ; Shift register 0
                              ; clock = OSCL bit 3,
                              ; Reset = Port A bit 0,
                              ; Direction = Port A bit 1
putr    SHIFT0, PORTB         ; Copy SHIFT0 working register to Port B

endp                          ; Marks end of PLC program
```

Listing 3.7. A simple shift register program (Lst3_7.asm)

```
include "16F887.PLC"          ; Defines PLC instructions

ld      OSCL, 7               ; Read OSCL bit 7 (Data input)
shift   0, OSCL, 3, PORTA, 0, PORTA, 1
                              ; Shift register 0
                              ; Data in = OSCL bit 7
                              ; Clock = OSCL bit 3
                              ; Reset = Port A bit 0
                              ; Direction = Port A bit 1
shift   1, OSCL, 3, PORTA, 0 , PORTA, 1
                              ; Chained shift register 1
shift   2, OSCL, 3, PORTA, 0 , PORTA, 1
                              ; Chained shift register 2
putr    SHIFT0, PORTD         ; Copy SHIFT0 working register to Port D

endp                          ; Marks end of PLC program
```

Listing 3.8. Chaining multiple shift registers (Lst3_8.asm)

```
include "16F627.PLC"          ; Defines PLC instructions
                              ; Latch controls shift direction
                              ; (direction changes when 1 reaches end)
ld      SHIFT0, 7             ; MSb of working register = Set input
latch   AUX0, 0, SHIFT0, 0    ; AUX0, 0 = Q output
                              ; LSb of working register = Reset input
eqi     PORTB, 0x00           ; Input a logic-1 if Port B = 00000000
shift   0, OSCL, 0, PORTA, 0, AUX0, 0
                              ; Shift register 0, clock = OSCL bit 0,
                              ; Reset using Port A bit 0 = 1
                              ; Direction = Q output of latch
putr    SHIFT0, PORTB         ; Copy SHIFT0 working register to Port B

endp                          ; Marks end of PLC program
```

Listing 3.9. A simple light chaser program

shift register's direction input and then using the state of the left and right bits of the shift register's output register to set and reset the latch, respectively.

If a single illuminated bit can somehow be 'injected' into the shift register then this pattern will continuously shift left and right, as the latch is set and reset. Thus, the remaining problem is to inject an illuminated bit into the working register in the first place.

In comparison

One answer would be to design a combinational logic circuit that would detect the binary pattern '0000 0000' and then automatically inject a logic 1 into the shift register. This is quite feasible, but a simpler solution would be to introduce an appropriate instruction from the byte comparison family of commands.

These commands either allow a register to be compared with a numeric value (immediate value), or permit two registers to be compared, with the command outputting a logic 1 if the result of the comparison is true. Available byte comparison types include:

- Greater than (immediate and register-based – gti and gtr commands)
- Greater than or equal (immediate and register-based – gtei and gter commands)
- Equal (immediate and register-based – eqi and eqr commands)
- Not equal (immediate and register-based – nei and ner commands)
- Less than (immediate and register-based – lti and ltr commands)
- Less than or equal (immediate and register-based – ltei and lter commands).

Thus, we can use the 'eqi' (equal to an immediate value) command to inject a logic 1 into the shift register, should the output register be empty. The resulting program is given in Listing 3.9, written for the PIC16F627/627A microcontroller.

Notice that the program uses bit 0 of Port A as the reset input. This is fine if you want the ability to manually enable and disable the output display. If you want to run the shift register continuously then it is possible to permanently disable the reset input, either in hardware or in software. The hardware approach is to physically ground the reset input, although this effectively wastes an input port bit.

You can also disable the reset input in software, by replacing the reference to PORTA, 0 with a reference which always returns a '0'. To this end, the PLC software provides a register with the name 'LOGIC', with bit 1 of this register preprogrammed to a value of '1' and bit 0 of the same register containing '0'. Thus, replacing the reference to 'PORTA, 0' in Listing 3.9 with 'LOGIC, 0' will permanently disable the reset function.

This is clearly a remarkably compact program, considering the complexity of the task performed. The main sub-tasks performed by the program are:

1. Using a latch to control the shift register direction.

2. Setting and resetting the latch when a non-zero bit reaches bits 7 and 0 of the shift register's working register, respectively.

3. Injecting a logic 1 into the shift register if the working register is empty.

4. Copying the shift register's working register to an output port, in order to make it visible.

5. Optionally allowing the display to be blanked by resetting the shift register.

To confirm your understanding of the program's operation, you should ensure that you can match each of the above descriptive points to the actual section of code performing that task.

Note that we'll be using a sequencer command later in the series to create much more powerful and flexible animated displays than those seen so far – and the associated programs will be even shorter!

Summary

Part 3 of the series has continued the tour of the PLC software's sequential logic capabilities, focusing on timers and shift registers. Low-speed and high-speed timers have been introduced, offering time delays ranging from four milliseconds to approximately 255 seconds. The configuration of on-delay and pulse output timers has been discussed, and these have been applied in applications as diverse as alarms and switch debounce circuits.

A range of shift register applications has also been developed. This has included the use of single and chained shift registers, repeating pattern displays based on oscillator bit inputs, and even a simple KnightRider-style display.

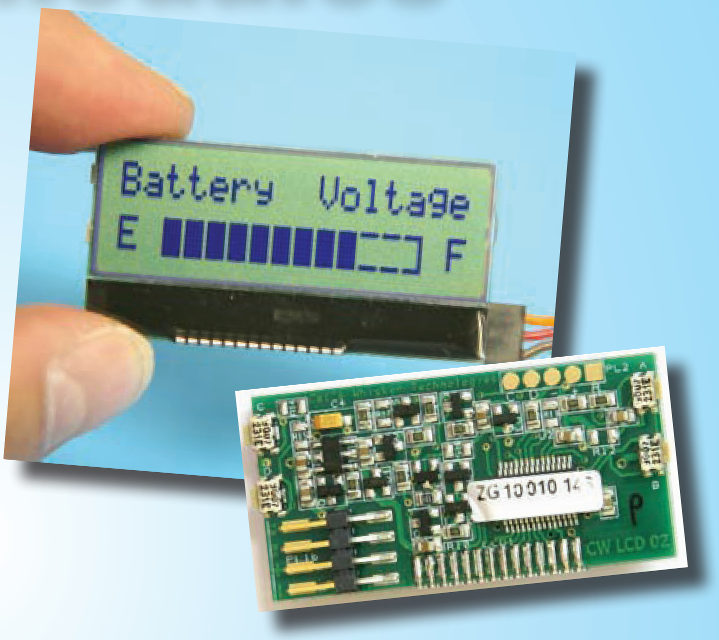
We have looked at the use of internal memory by the PLC software, and have seen how this knowledge could be used when debugging PLC software, either by adding watch statements, using a suitably capable IDE, or by adding debugging instructions to programs. A number of byte processing instruction categories has also been introduced and used to simplify the coding of programs (selected byte transfer and byte comparison commands were used).

Next month

The next part of the series will introduce further sequential logic capabilities of the PLC software, including counters and the creation of pulse-width-modulated (PWM) signals.

WORTH £25 EACH

Win one of 10 TextStar 'stick-on' LCD modules



EVERYDAY PRACTICAL ELECTRONICS is offering readers the chance to win one of ten TextStar 'stick-on' LCD modules from Cat's Whisker Technologies.

The TextStar module is an incredibly easy-to-use serial LCD module. The TextStar module is packed with features that make it attractive to hobbyists and professionals alike. Key features include:

- UART serial port working with TTL or RS232 level signals
- Super-easy bargraphs using unique 'GraphSmart' technology
- Ultra-thin design allows it to be stuck on, or even used as a handheld device
- Menu driven set-up with built in buttons
- Works on supplies from 3.5V to 20V
- Electrically robust so that incorrect connection will not cause damage
- 2×16 physical character display with 16 virtual lines
- Special servo-signal tester mode for r/c enthusiasts
- Terminal mode – allows the set-up button to be used to send data back to the host
- Plus lots of other built-in features

Cat's Whisker Technologies owner Nigel Fraser Ker initially designed the module for use within the company "We needed a display that we could easily adapt to different projects, but all the commercially available ones were either too bulky or fussy about baud rates, etc. That's how the TextStar came to be designed."

GRAPHSMART

GraphSmart makes bargraphs really easy. For example, the bargraph pictured above is 12 characters long and at a value of 75%. The sequence of characters sent to display this graph would be a 254 (control character), the letter 'b' which stands for 'capped bargraph', character 12 (the length) and character 75 (the percentage). That's all there is to it! So, to create the whole of the above display, the sequence would be as follows:

```
BATTERY  VOLTAGEE  <254>b<12><75>  F
```

GraphSmart takes all the hard work out of creating really professional looking bargraphs

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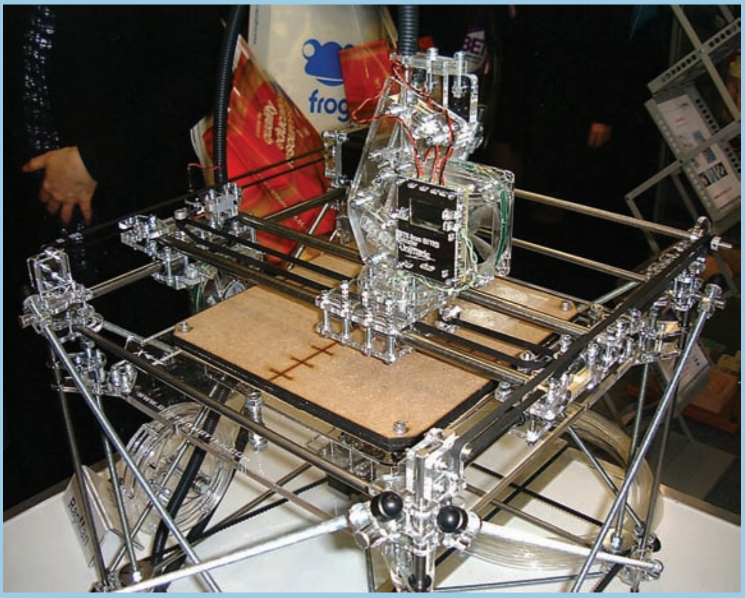
RapMan – The 3D Printer

Part 2

by Mike Hibbett



Introducing the 'RapMan' a low cost 3D Printer – it stands out from the rest!

LAST month, we described a low-cost 3D printer design, RepRap, which is simple enough to be built by the dedicated hobbyist. Constructing one of these machines from the basic design would, however, be a real challenge and would involve sourcing components from many different suppliers in the UK and USA.

Fortunately, two companies, MakerBot in the US and BitsFromBytes in the UK have produced kits based on the original RepRap design. The BitsFromBytes product, RapMan V3, contains a number of improvements over the original RepRap design, and we have been fortunate enough to get hold of an early release of the kit to evaluate.

One of the main attractions for us of building the kit, besides the obvious novelty of being able to print solid plastic objects, is the opportunity to relive the 'Heathkit' experience. Heathkits were electronic kits sold by the Heath Company in the USA from 1947 up to the late 1980s, and they were extremely popular in their time. All kinds of kits were manufactured, from oscilloscopes to colour televisions.

One thing the kits had in common was a beautifully illustrated construction manual and the huge sense of achievement once the build was complete. There has been nothing to replace the Heathkit concept, so we were interested to see if RapMan could fill the void.

On delivery

Needless to say, our anticipation rose as the delivery date drew near. When the kit finally arrived, it came in a surprisingly compact cardboard box, although it did weigh over 15kg!

The contents were very well packaged, with the box containing over 1680 individual components – this is not going to be a quick assembly job. The parts are shown in Fig.1.

A couple of items are not supplied with the kit, and you must source

Fig.1. Having unpacked the kit, it weighs just over 15kg. You only have 1682 parts to check out!

yourself. A standard IEC mains cable and an SDMedia card, which you use to transfer the print files from the PC to the printer. As print files are typically just a few MB a small 1GB SDMedia card will be more than sufficient.

Also missing from the kit are any instructions. This is intentional, as the build and user guides are in electronic format, and downloaded from the website. At 100MB, the build manual is quite a sizable file, but for good reason.

Virtual manual

Construction manuals have come a long way since the Heathkit days. While we do miss the printed book, with its beautifully hand-drawn figures, the RapMan 'manual' comes with some stunning effects. It's an Adobe pdf format file and you will need to use Adobe Reader version 9 or later to view it properly.

It starts off with a list of components (all 1682 of them!) and a discussion on construction techniques, and then lists each construction sequence in turn. The format is basically the same, with two pages for each sub-assembly.

The first page shows an image of the fully assembled part you will be constructing, listing the components and tools required. The next page shows an animation of the actual construction steps. What is quite astonishing, however, is that the animation can be paused, rotated to any angle, resized, and even components removed from it – and the animation resumed.

The pdf file contains a full 3D representation of each sub-assembly, with every single component individually identifiable and manipulable. It makes assembly a breeze, especially for those of us who are not mechanically minded. An example page can be seen in Fig. 2.

Kit contents

Over half the weight of the kit is due to the framework parts, which are made from bright zinc-coated steel. A large bag containing over one thousand nuts and bolts adds to the realisation that this is not going to be a quick construction task.

One of the more intriguing items is a set of plastic parts shrink-wrapped to a large sheet of expanded polystyrene. These are custom laser cut components cut from acrylic sheet and left in place, ready to be 'popped' out by hand.

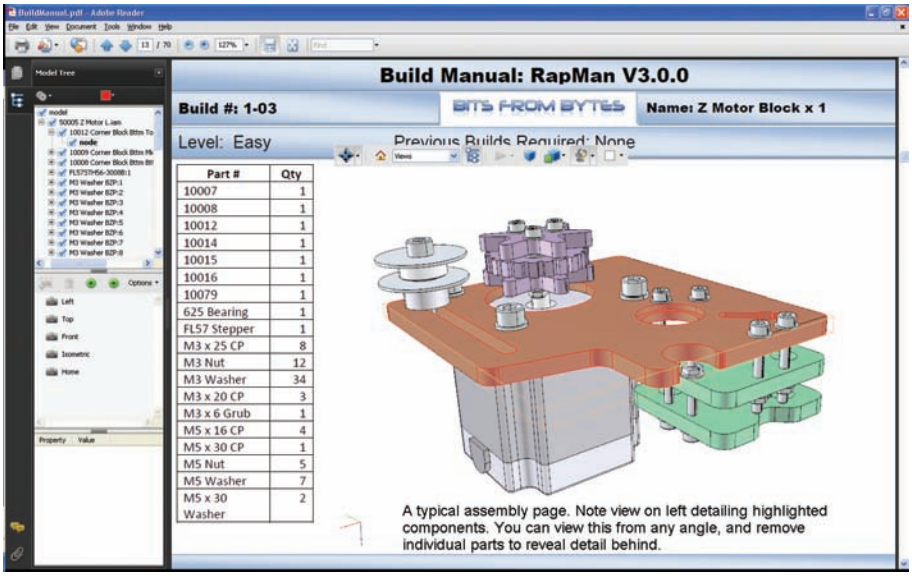


Fig.2. Typical 'manual' screen page. Assembly is a breeze using the animation feature: you can view the image from any angle and even remove individual components

We had to resist the temptation to pop them all out and remove the sticky plastic coating; there are over a hundred individual parts and some are very similar, with the only way to identify them being a diagram of the complete sheet within the build manual. A few had dropped out in transit, but were easily identified.

Getting organised

It was dawning on us by now that an organised approach to assembly was called for. A storage system for the components, in particular the laser cut plastic parts, and a clear surface to work on were required. Like many hobbyists, we were not fortunate enough to have a dedicated workshop or spare room available, but the kitchen table – once the children had gone to bed – turned out to be perfectly adequate. Although, as you can see from Fig. 3, assembly really is child's play, and it is safe to let them join in! This figure also shows that a soft mat is very useful during assembly, as small nuts and bolts can be easily brushed off the table, as we soon discovered.

The manufacturer had indicated that there could be upwards of twenty hours construction time involved in the build, so we planned to work over a weekend and a number of evening sessions. A systemised approach soon arose: take out just the parts required for the next

Fig.3. Construction – it's child play!

build step, get the tools together, pack away the kit and then settle down to an evening building. Each step was easily achievable in a short one- or two-hour session, and so there was always a feeling of achievement at the end of each session.

Tools

The designers of this kit have given a lot of thought into minimising the tools that would be required to construct the machine. Several small spanners are required, which will probably require a search on eBay or Amazon, but apart from these, the tools will either already be in your toolbox or available cheaply at your local hardware store. Several ball-ended Allen keys are required, but we found that a cheap multi-key tool from the hardware store worked perfectly. A low wattage soldering iron is also required.

All these tools are useful items anyway, and as we have found since building the kit, they come in handy for assembling some of the objects we make with it. This machine turns you into something of a mechanical engineer, even if you didn't start out with that in mind!

Construction

As can be see from Fig.2, the assembly process it not complicated, although some stages can be a bit fiddly. It was interesting observing a seven-year-old child assembling one of the sub-assemblies while referring to the 3D model on the computer screen, rotating the model to get a better view. The kids today, they don't know how lucky they are!

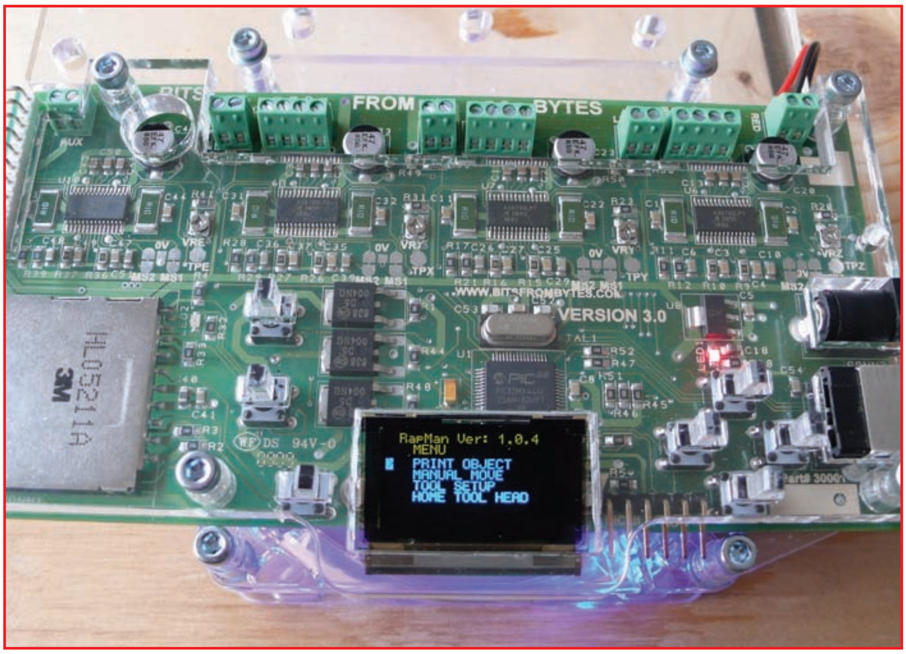


Fig.5. The electronics driving force is based on Microchip's PIC32 microcontroller

Despite the organised approach and the help of some young assistants, the first half of construction doesn't yield any apparent progress, as you are mostly constructing small sub-assemblies that will be used later in the build. By about page 47 of the 83-page manual, however, things start taking shape, and you quickly arrive at the basic frame of the machine, as shown in Fig. 4.

At this stage in the process we'll take a look at the one pre-built assembly, the brains of the kit, shown in Fig. 5. This is a powerful micrcontroller system based on the Microchip PIC32. It's equipped with four stepper motor controllers, an OLED display, SD-Media card slot and a USB interface.

At the moment, the USB interface is only present for firmware updating, and indeed the software has gone through several revisions in the last few months. You may wonder why the USB interface is not used as a direct connection to the PC for printing; the reason is that the printer is designed to operate completely standalone.

Large complex prints can takes several hours, so being free from the PC can

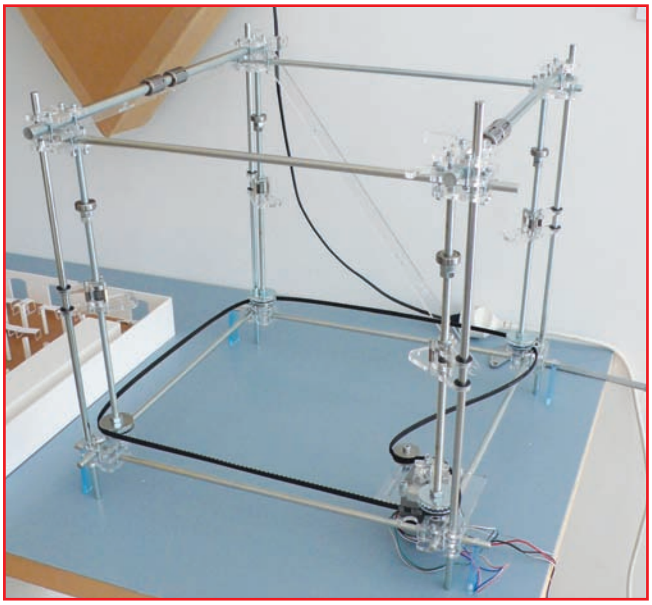


Fig.4. Partly constructed framework

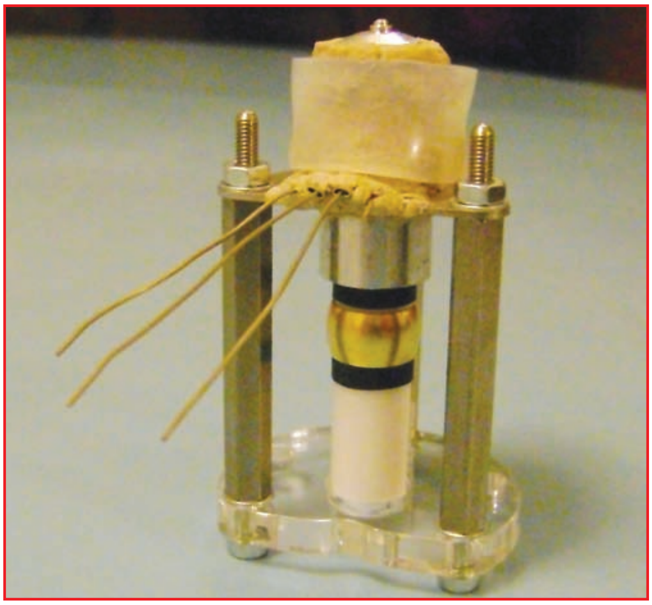


Fig.6. Fully assembled heater barrel

EPE Reader Offer

The RapMan printer kit is available from **www.bitsfrombytes.com**. For readers of *EPE*, BitsFromBytes are offering a 15% discount on all products. Just enter the code **EPEYRK** when prompted for a coupon code on the Cart screen prior to Check Out.

save a lot of energy. This, we feel, shows a consideration for the environmental impact of the printer, and should be applauded.

Extruder

With the construction of the main printer complete, it was time to move onto the extruder head. BitsFromBytes have anticipated presenting a number of different 'heads' to their machine, with the plastic extruder being the first. (A Dremmel milling head, and even a chocolate extruder are in the works.)

The extruder head has it's own 30-page construction manual, and this is where things start to get a little fiddly.

The heat is on

At the heart of the printer is the heater barrel. This is a custom machined metal tube with a PTFE collar through which the plastic material is pushed, melted and then squeezed out as a very fine, consistent thread.

The temperature and flow rate are very carefully controlled to enable the thread to fuse to the top layer of the object underneath it, while being accurately positioned by the three stepper motors on the printer body. It's a precision piece of equipment, and one that you must assemble yourself.

Once again the designers have gone to great lengths to simplify the design and describe its construction clearly, so the job becomes a 'fiddly' task rather than one requiring any skill. The tricky part is building up layers of fire cement onto the barrel body, then wrapping heater wire round the body and placing a further coating of fire cement to seal it all in.

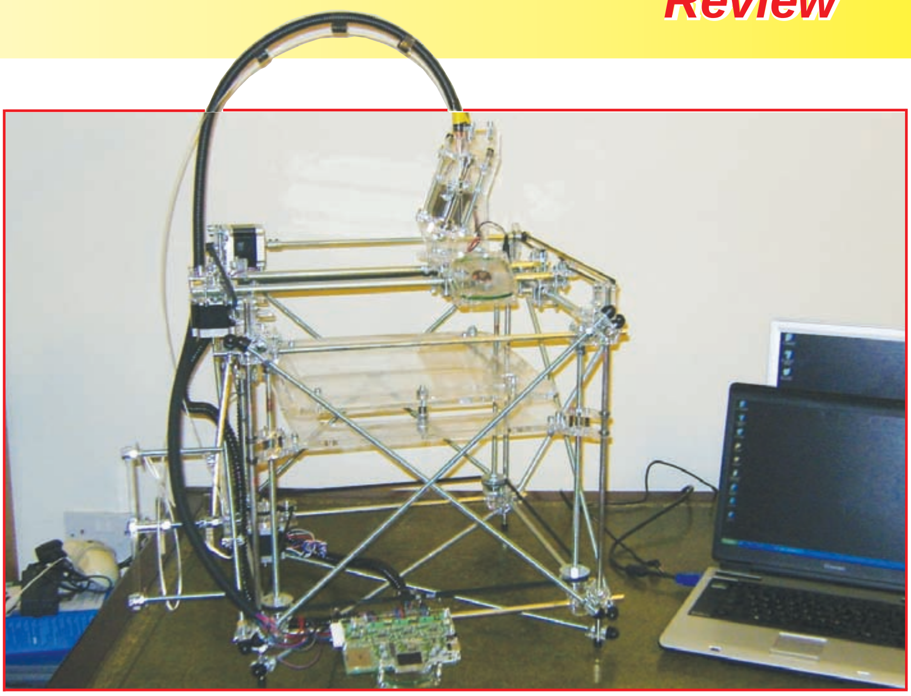


Fig.7. The completed RapMan 3D Printer

This task alone took two hours with several repeated attempts, but the final result was acceptable (even if we did leave one of the wires a bit on the short side.) The completed heater can be seen in Fig. 6.

With construction completed (Fig. 7.) there was just a few minutes of adjustment to get the print surface flat before we were ready to try our first test print.

Printing will be a subject for next month, but to whet your appetite, an example print is shown in Fig.8. It was quite unnerving, loading a file of the cup into the printer, leaving the room for an hour and then returning to find a real cup sitting where once was empty space.

Fig.8. As if by magic, the first test run produced this cup!

Conclusion – so far

Just as with building a Heathkit in the 1980s, by the end of construction you feel that you really *understand* how the unit works, having placed every single nut and bolt. It's been a fantastic journey and utter fun.

So that's the end of the construction stage, but this isn't the end of the story. Putting this machine to good use requires becoming familiar with specialised 3D design and modeling software.

Fortunately, there is quite a wide range of free applications available that suit a wide range of needs and skills. One in particular, CoCreate by PTC, is a commercial program that is offered free for personal use and has proven to be very simple to use.

Next month, we will take a look at how to use CoCreate to produce a design for a project case and then print it with RapMan.

Max's Cool Beans

By Max The Magnificent

I'm a reading fool!

With regard to the title of this column, my mom says that the word 'fool' is superfluous, and she used to be a lecturer at college, so who are we to argue? But we digress...

A couple of days ago (as I pen these words) a friend asked me if I would write an article about a local school that specializes in teaching dyslexic kids. It turns out that my friend is severely dyslexic himself, and he is very involved with the school. A local magazine had offered the school a big centre-spread as a local interest story, but for obvious reasons my friend didn't feel able to write the piece himself.

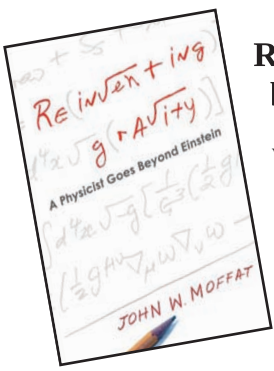
So, I took a couple of hours off work, trundled down to the school, interviewed the head and teachers, met the kids (who all seemed to be having a wonderful time), and generally discovered a lot of interesting things I had no clue about before. That night, I wrote everything up, and the next day I submitted it to the magazine.

I'm a victim of my own success (ah!). Almost immediately, the magazine came back and said that their current lead article on a nearby community now seemed a bit wishy-washy by comparison. The bottom line is that they want me to go out and interview the local folks and re-write their article for them (at least I'll get paid for this one [grin]).

But, once again, we digress... I discovered just how difficult it is for dyslexic children to read – painstakingly sounding out the letters and trying to blend them together to form words – by the time they've worked out what the current word means, they may have already forgotten the rest of the sentence. It made me realize how lucky I am, because I love reading with a passion.

In fact, in addition to a bunch of magazines, I usually read several books a week – typically a science fiction tale or two, possibly a historical drama, and often one or more books on 'stuff' like maths, physics or biology (whatever has received good reviews in magazines or on the web).

So why am I waffling on about this? Well, I thought I would share a couple of amazingly interesting books that I've read over the last few weeks, ones that have set my head spinning...



Reinventing Gravity by John Moffat

Gravity is one of those things that we typically take for granted. Most of us consider ourselves to be at least passingly familiar with the work of Newton and Einstein, but I for one was surprised to discover just how little I know...

Reinventing Gravity is a wonderful book. The author, respected physicist John Moffat, doesn't assume that the reader has any form of expert knowledge. Instead, he starts by walking us step-by-step through the various theories of gravity, from Aristotle to the present day.

Along the way we grow into an appreciation of a different way of looking at things. For example, most of us are aware that in his *Philosophiæ Naturalis Principia Mathematica*, published in 1687, Sir Isaac Newton described his theory of universal gravitation.

At first this theory seemed to completely describe the motions of the planets and the stars, and led to the idea of a 'clockwork universe'. One very interesting aspect to all of this occurred when astronomers began to realize that there was a problem with regard to the 'anomalous precession of the perihelion of the planet Mercury' (which is the clever way of saying that Mercury wasn't orbiting the Sun as expected).

The folks of the time absolutely believed in the theory of Newtonian gravity, so they looked for an explanation in this context. The idea they came up with was that there was a – as yet undiscovered – planet (which they called Vulcan) in orbit between the Sun and Mercury. Based on this proposal, many folks devoted huge amounts of effort and ingenuity trying to find a planet that we now know does not exist.

Then Albert Einstein came along with his theory of general relativity. Among other things, this accurately predicted the orbit of Mercury without the need to introduce a 'fudge factor' in the form of a non-existent planet.

For close to 100 years, general relativity has been accepted by the majority of folks as fully describing gravity. But once again there's a problem. Astronomers have discovered that the stars at the edges of rotating galaxies are travelling much faster than they should be... so fast that they should fly off into space... but they don't.

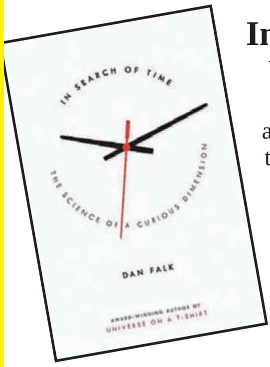
In order to address this, folks have come up with the concept of 'dark matter'. The idea in a nutshell is that dark matter is something we can't 'see' or 'taste' or anything like that... except through its gravitational interactions (the posh way to say this is that 'dark matter is hypothetical 'stuff' that does not interact with the electromagnetic force, but whose presence can be inferred from gravitational effects on visible matter').

Doesn't this seem a little strange to you. It certainly does to me. The idea is that we are so accepting that general relativity fully defines gravity that when we make observations that don't fit we simply invent some invisible matter to make everything work. And don't even get me started about other galaxies, like NGC 4736, which seem to lack dark matter.

And so we come to the author's MOG (modified gravity) theory, which addresses this conundrum. Even more exciting, MOG also eliminates the need for the singularities at the centre of black holes (which solves lots of problems) along with the singularity at the beginning of creation (no more 'big bang' *per se*).

Of course, this is still just a theory, but the author also describes some observations and measurements we could make that should resolve the issue as to which gravitational theory is correct. The really cool thing is that we (the human race) should have the technological capability to make these measurements in the not-so-distant future (perhaps in the next few years). I, for one, can't wait!

In Search of Time by Dan Falk



In his book, *In Search of Time*, the author Dan Falk walks through the theories of time, from our earliest ancestors' perception of time, to the development of various calendars, to today's world of atomic clocks.

I must admit that I have a bad habit. When I'm in the process of reading a book and I need to take a break, I fold the upper corner of the right-hand page and use it as a bookmark. The other three corners I fold as necessary to keep track of interesting tidbits of trivia and nuggets of knowledge. So, you may be interested to know that my copy of *In Search of Time* is bristling with folded corners, marking a plethora of fascinating facts.

It's difficult to explain just how great this book is. Suffice to say, that *In Search of Time* boggled my mind. Like most folks (or at least most folks I know), I would have said that time seems to be a fairly obvious concept ... until you read this book.

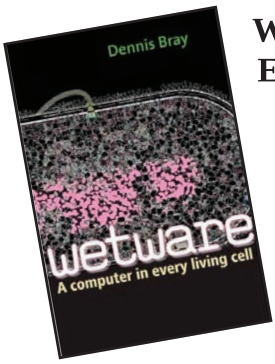
I was amazed to discover that Saint Augustine of Hippo (AD 354-430) spent years pondering the problem of time. As he famously commented: "What, then, is time? If no one ask of me, I know, but if wish to explain to him who asks, I know not." Having read this book, I know just how he felt.

When I started to write this review I had all sorts of points I wished to present... but when I come to try to explain them I run into the same problem as Saint Augustine. This is not to say that *In Search of Time* does a bad job of explaining things ... it's just that the things it's trying to explain are so mind-boggling that ... my mind is boggled.

Note that we are not talking about complex mathematical equations or anything like that. It's the philosophical issues that bring you to your metaphorical knees (did time exist before the 'big bang', or did the big bang bring time into existence?).

The bottom line is that this book is **strongly** recommended. And, if having read it you understand what time is, please drop me a line and explain it to me.

Wetware: A Computer in Every Living Cell by Dennis Bray



I've saved the best for last. How does a single-cell creature, such as an amoeba, lead such a sophisticated life? How does it hunt living prey, respond to lights, sounds and smells, and display complex sequences of movements without the benefit of a nervous system? This book of offers a startling and original answer.

Wetware: A Computer in Every Living Cell is an incredibly thought-provoking book. The author, Dennis Bray, writes in a very clear, understandable, yet vivid style. Early in the book we are introduced to the amoeba. Even though this is only a single-celled creature, it can 'crawl' around, hunt for food, and respond to external stimuli, like lights and sounds and smells... all without muscles or a nervous system.

How can this be? Dennis walks us through the concepts of things like proteins and explains how – in the case of the amoeba – interactions between different proteins can be used to detect external stimuli, perform 'computations' and 'make' decisions, cause the amoeba to move in its 'desired' direction, and so forth. Dennis also describes how these structures could have originated and evolved over time.

If the book had stopped at this point it would still have been worth ten times what I paid for it... but this is only the beginning. Dennis then moves on to describe how colonies of single-celled creatures (some with a nucleus like an amoeba, and some without a nucleus like bacteria) can perform 'quorum sensing', which allows them to detect the presence of others of their kind and – more significantly – how many of them there are (few, many, very many...).

Then we move on to consider simple multi-celled creatures. Here we discover how the different cells forming the creature manage to communicate with each other. I had never really appreciated the complexities of all this before, but having been exposed to the first part of the book I was awed by the beauty of all this.

And we keep on working our way up through larger and larger organisms until we reach creatures such as ourselves. Intellectually, of course, I was already aware that my body is formed from trillions upon trillions of cells. But reading this book really makes you think about how amazing it is that these all work together in the way that they do.

I mean, there are several trillion cells forming my brain. How do they all interact with each other? Don't talk to me about nerve cells and synapses and suchlike. I used to be relatively confident that I had a good layman's grasp as to how all this stuff worked (in general terms at least). Having read this book, I realize that I know less than nothing.

In summary, this book literally 'blew my mind'. I read it several weeks ago as I pen these words, yet I'm still pondering the things it taught me on a daily basis. I would strongly recommend this book to anyone and everyone. This is a 'must read!'

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Real Time Operating Systems – Part 4

In last month's article, we described the installation of the FreeRTOS operation system source files, and outlined a simple test application to run on a PIC24 processor. This month, we go into the design of a simple yet practical application – a binary clock. (We may differ here on the definition of 'practical', but it is a great geek toy and useful for teaching binary to children.)

A binary clock is a device that displays the time (hours, minutes, seconds in our case) in the binary system, rather than decimal. So, rather than show, say, 12:34:56, it displays

1100:100010:111000

We will show this on three rows of LEDs. Hours can be displayed with four LEDs, minutes with six and seconds with six.

With a pushbutton switch added to allow setting of the time, it means our design will require 16 output pins and one input pin from the processor, which can be accommodated easily by our development circuit described last month. The combined circuit is shown in Fig.1.

If you build this circuit then you may want to construct it on two boards, keeping the 'development circuit' on it's own board, so it can be reused at a later date. We built the circuits on stripboard, with header pins on the controller development board to ease connection to other circuits. Our prototype example boards are shown in the accompanying photographs. Next month, we will describe the design of a case for these two boards. So, if you do intend to build it as a practical clock, you might want to follow our layout.

Example application

Before we describe the application and its use of FreeRTOS, we need to understand a little better what we want our application to do. So here is a simple specification:

On power up, the clock will start with a time of midnight, and will update the display once every second. If the pushbutton switch is pressed and held for two seconds

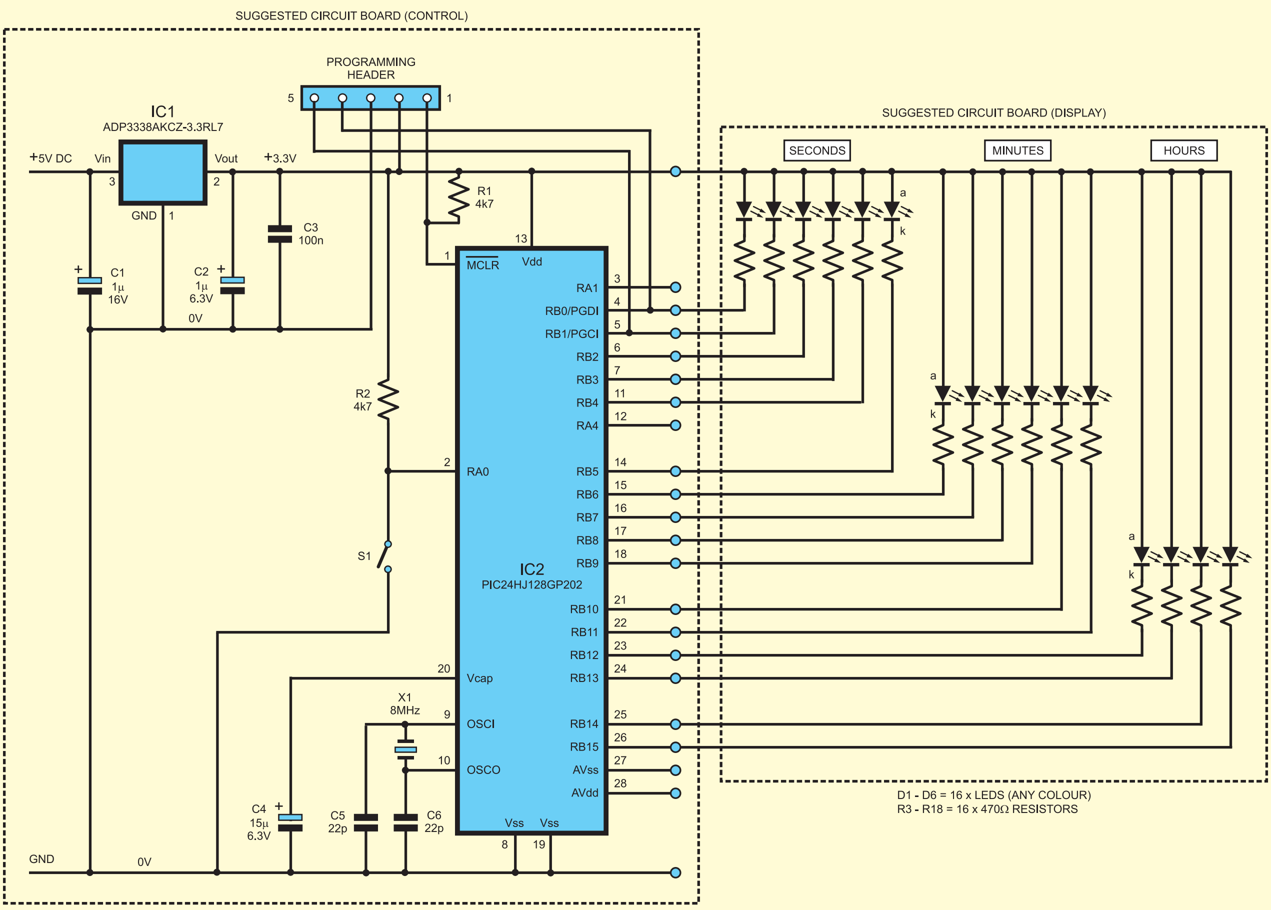
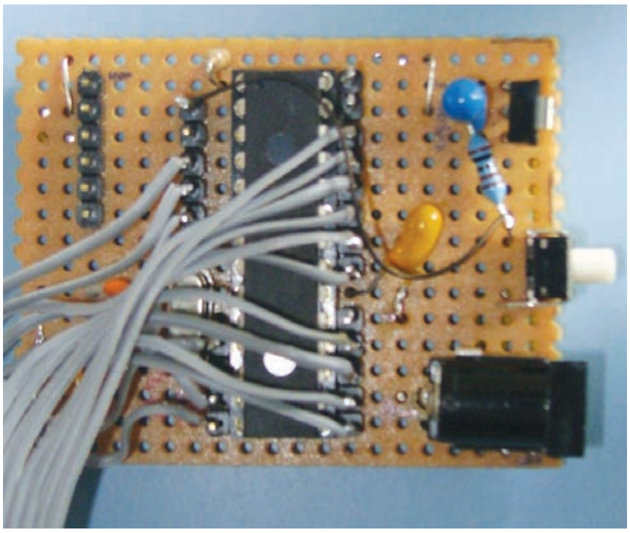


Fig.1. 'Practical' circuit diagram for the Binary Clock

then the minutes will increment at a rate of ten minutes every second. If the pushbutton is released briefly and then pressed, the minutes will update by one minute every second. If the button is released for two seconds, the clock will start running normally. The clock will display time in 12-hour mode.

The specification completely covers what the application needs to do. As we mentioned last month, a design like this could be expressed in a few hundred assembly language instructions, so you might wonder what is the point of writing it in C, and using an operating system. Well, there is certainly nothing wrong with writing this in assembler, and we probably would have. It makes, however, a simple enough 'real' application, and makes clear the potential of an operating system. A larger example would have clouded the important details.



Prototype control circuit components mounted on a piece of stripboard

Design time

The next step, before actually writing the code, is to *design* the application. A simple design such as this is typically 'fleshed out' by writing down the sequence of events, at a high level, starting from power-up. This then serves as a basis for the code implementation – the high level descriptions serving as comments for each block of code. Complex descriptions could be further broken down into a sequence of less complex descriptions until you have a clear enough definition to start writing code.

This approach is fine, but where an application is designed with an operating system, we also need to think about how the code will be partitioned into independent tasks, and how these tasks will communicate with each other. For this, we use a diagram that shows tasks as circles and messages sent between them as lines with arrowheads – see Fig.2.

You might think this is introducing an added layer of complexity, but it is actually the key to making software design easier, and scalable. Not only do you have two different views of your design, but you are taking the time early on to break the problem into clear, independent blocks of functionality.

These blocks are much simpler than the project as a whole, and can be coded, tested and debugged in isolation of each other. Like the proverb 'How do you eat an Elephant', you can approach the problem one bite at a time.

Fig.2 shows the task interaction diagram for the project, and Fig.3 the top level sequence of events for the 'Main()' routine. We have written this directly into a C source file as comments so we can start filling in the code immediately, if we wish. As you can see in Fig.3, there isn't much to do when setting up the RTOS environment, and in the final implementation this results in less than 20 lines of actual code.

```
int main( void )
{
    /* Set CPU speed */

    /* Configure I/O pin directions */

    /* Define message queues */

    /* Create tasks */

    /* Start the Scheduler */

    /* We should never reach here */

    return 0;
}
```

Fig.3. Top level sequence of events for the 'Main()' routine

Task interaction

Fig.2 could use some explanation, as it's a format we haven't used before in *PIC n' Mix*. The diagram shows how tasks (shown as the circles) interact with each other. The actual functionality of a task is not shown; this level of detail is irrelevant here.

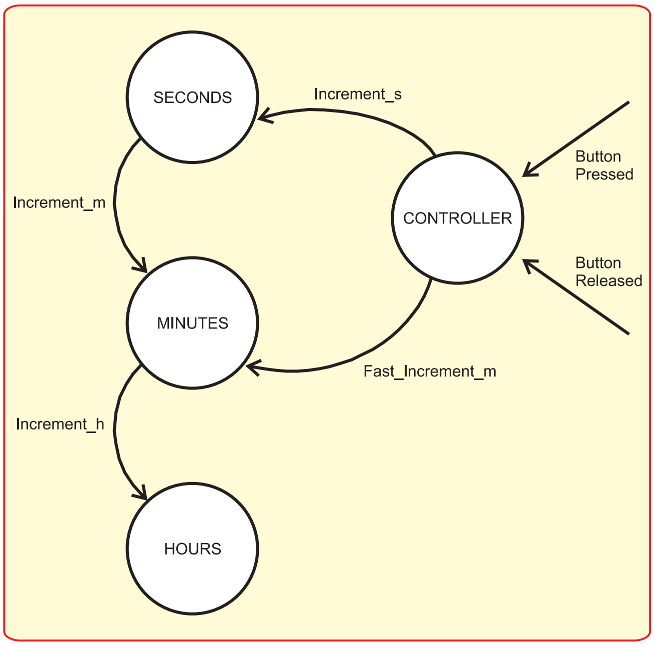


Fig.2. Task interaction diagram for the 'clock'

Instead, we are showing what *messages* are exchanged between them.

Messages are indicated by the lines with arrow heads, with the direction of the arrowhead indicating the direction in which the message is flowing. So, for example, the 'Controller' task can send an 'Increment_s' message to the 'Seconds' task, and can also send a 'Fast_Increment_m' message to the 'Minutes' task.

The 'Controller' can also receive two messages, which on the diagram appear to come from nowhere. These are messages that come from the outside (often referred to as *the environment*) and in our case are generated by an interrupt routine that is monitoring the interrupt pin to which the pushswitch is connected.

Messages can be implemented in an RTOS in a number of different ways, but we will use a **queue,** since this is simple to use and flexible. Each task has been assigned a single input message queue from which it awaits messages.

If no messages are present, the task will block (stop using CPU time), but when one or more messages appear it will start up again (once the OS has scheduled it to run), extract a message and process it. Once the message has been dealt with it will look in the queue again; if there are no further messages, the task will go back to sleep.

This is a fundamental design approach to a good real-time system: *each task performs an action in response to an input, and then stops, waiting for a further input*. In an ideal real-time system you would not expect to see any tasks waiting to run; they should all be blocked, waiting for an input. When that input arrives (such as a key press, or a packet of data over a network) there will be a flurry of activity and then the system returns to inactivity.

Of course, this switching from inactivity to activity could be happening very quickly, to our eyes. RTOSs are, however, designed with this in mind and react *very* quickly, passing messages around and starting/stopping tasks with the absolute minimum of overhead. This 'OS overhead' is a key metric by which RTOSs are judged, and is something FreeRTOS performs very well.

Each message is simply a small number of bytes, the length and content of which are completely defined by us. In such a simple system as this, we will use a single byte, the contents of which is a number indicating the name of the message, as seen in Fig.2. There are no additional parameters

involved in our case, which helps to keep the message processing simple.

Application operation

So how will our task interaction, as shown in Fig.2, achieve the requirements that we set out for our application?

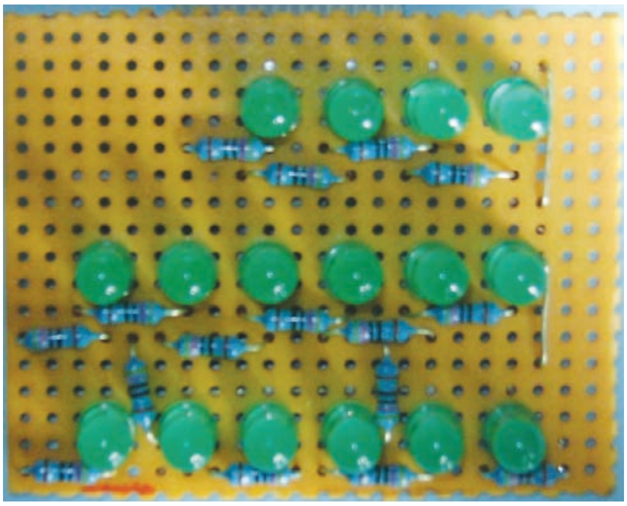
The Seconds, Minutes and Hours tasks are each responsible for storing the current value of their respective time value, and outputting it onto their respective LEDs. When a message arrives at their input queue, they simply update their time value and change the state of their LEDs. In the case of seconds and minutes, should their value wrap back to zero, they send an increment message to the next task.

The Controller task is responsible for sending a message to the Seconds task once every second to maintain the time. The Controller also handles the processing logic for the keypresses; when a key press is detected it will stop sending period increments to the Seconds task and will instead send Fast_Increment messages to the Minute task, at a rate to meet our needs. If we decide to change the logic of how the keypresses work, or even add another button to simplify the setting of the time, then only the Controller task needs to change – the other three tasks are guaranteed to be unaffected.

Interrupts

The interrupt routine that handles the button presses is written as you would normally write an interrupt, since it works outside of the RTOS. The only difference is in the way in which it communicates with the other parts of the system. Normally, you would write to a variable that is 'polled' by other parts of your software; in an OS environment you use a special function call to send a message to a task.

Using interrupts for the pushbutton detection may appear overkill for those of us who are uncomfortable with writing them (and to be honest, getting interrupts working is still something that gives the author headaches), but it is essential in most cases so as not to interfere with the smooth running of the system. It is acceptable to have a task that periodically polls an input pin, so long as the poll period is long, for example every few seconds or so, and does not consume a lot of time.



Prototype 'time' display stripboard component layout. Reading from top to bottom; hours row (four LEDs), minutes row (six LEDs) and seconds row (six LEDs)

Reacting to user input is something we want to be very fast at, and so an interrupt provides the best way of isolating your application design from the issue of polling for keypresses, while allowing everything else to work. It is also an architecture that is easier to modify and extend.

The full source code and build files for this project can be found on the *EPE* website. If you wish to use the software with the circuit shown in this article, simply build the project in MPLAB, export the .hex file and load it onto your circuit using a PICkit2 programmer or similar.

Although we have used some of the programming pins to drive LEDs, the programming interface will still function with the display fitted. And if you do find yourself tempted to build this circuit then remember to take a look at the article on 3D printers in next months issue, as we will be showing a case design for it!

In this series we have glossed over many issues, such as setting task priorities, but we hope we have raised your interest in this fascinating subject and that you might be tempted to try it out. In a later article we will take a look at how the MPLAB simulator can be used to debug applications built with an operating system, but next month we will return to the subject of PIC-based video generation, and reveal the winner of the XGS Game System challenge.

Using Transistors as Switches

NOEL, a frequent contributor to the *EPE Chat Zone* forum, (**www.chatzones.co.uk**) posted a question about using a transistor as a simple switch.

I have attached two circuit diagrams (Fig.1a and Fig.1b). I am using the transistor as a simple switch to energise a relay coil. I have found that when the circuit is arranged as in Fig.1a, the relay will not switch, but when arranged as in Fig.1b, it switches normally.

Can anyone explain to me why this might be? I would have thought that the relay would operate in either configuration.

Other forum users were quick to provide the fundamental reason for the problem: the circuit in Fig.1a is an emitter follower, so the voltage at the emitter (e) (and hence across the load) is about 0.7V below the base (b) voltage (the emitter follows the base in this way). This transistor configuration is also referred to as common collector.

As the base drive is 5V (probably from a digital circuit) the maximum emitter voltage is 4.3V and is insufficient to activate the relay. A higher base drive voltage would allow the relay to be switched.

Thus, we have a straightforward answer, but it is worth looking at the use of transistors as switches in more detail. The emitter follower circuit may seem like a poor choice, is this always the case and what happens if one side of the load has to be grounded?

Switching requirements

Before proceeding, it is worth thinking about the switching requirements demanded by Noel's circuit. He does not give any details about the relay or the transistor apart from the relay's coil resistance. A coil resistance (load) value of 80Ω is common for 12V relays, and it is easy to find a number of examples. A simple calculation of V/R gives us a nominal current of 12/80 = 150mA for operating the relay.

Other relay specifications that might be of interest are listed below. Typical values are given as an illustration, but readers should check the actual data for any relays they use because they may vary significantly from those stated below.

Maximum coil voltage – the maximum voltage which can be applied without causing damage to the coil. A typical value for a 12V relay might be about 15V.

Pull-in voltage – the minimum voltage at which the relay will activate its contacts.

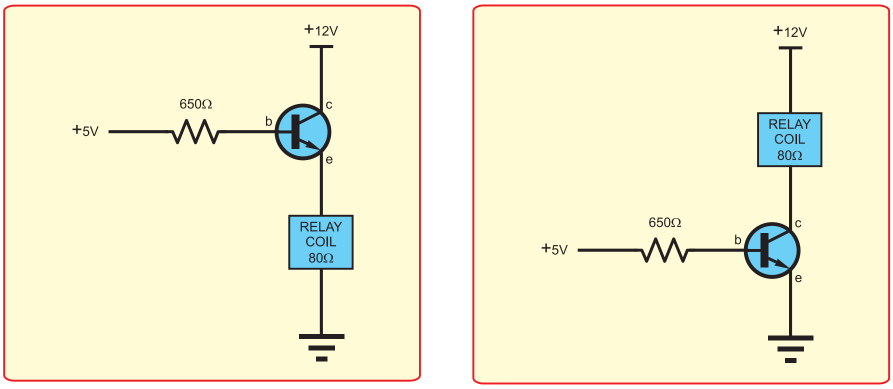


Fig.1. Noel's circuits (a) and (b) – see text

The initial voltage applied to switch the relay must be at or above this voltage to ensure reliable operation. A typical value for a 12V relay might be about 9V.

Drop out voltage – the voltage required to hold the contacts after they have been activated. This will be lower than the pull in voltage. Once a relay has switched it takes less applied voltage to hold the contacts in place than it does to move them initially. A typical value for a 12V relay might be about 4V.

Region of operation

A bipolar transistor contains two diode (*PN*) junctions, this is true of both *NPN* and *PNP* transistors; the junctions are simply the opposite way in the two types, requiring opposite voltages for the same operation.

The two junctions can be either forward biased (on) or reverse biased (off), so there are actually four different regions of operation for the transistor. These are shown in Table 1. When using transistors in circuits it is important to make sure they are in the appropriate region of operation. When a transistor is used as a switch it is usually switched between the *saturation* and *cutoff* regions.

In the cutoff region, both junctions in the transistor are reverse biased and no current flows through the transistor (except some leakage current); thus a transistor-based switch will be off. The very low current flow through the cutoff transistor ensures that very little power is dissipated in the transistor when the switch is off; however, care must be taken to ensure that the maximum collector-to-emitter voltage, V_{CEmax}, is not exceeded.

Saturation is characterised by a small voltage drop between the collector and emitter (called V_{CEsat}), which is typically around 0.1V to 0.2V. In the saturation region both junctions are forward biased, so each junction will have about 0.7V across it. For example we might have V_{BE} = 0.75V and V_{BC} = 0.70, the collector to emitter saturation voltage (V_{CEsat}) will be the difference between these, in this case 0.05V.

A transistor-based switch is on when the transistor is saturated. The low voltage drop from collector to emitter means that the power dissipation is not excessive, even for relatively high load currents; however, care must be taken to ensure that the maximum collector current, I_{Cmax}, is not exceeded.

Table 1: Bipolar transistor regions of operation

Base-Emitter Junction Bias	*Base-Collector Junction Bias*	*Region of Operation*	*Comment*
Forward	Forward	Saturation	Switch ON
Forward	Reverse	Reverse Active	Poor amplifier, specialist uses
Reverse	Forward	Forward Active	Good amplifier
Reverse	Reverse	Cutoff	Switch OFF

The forward active region is used for amplifiers; where normally we would want to avoid saturation as it would probably imply clipping of the signal. The base-emitter junction will be forward biased, with typically around 0.7V across it (V_{BE}); actual values being slightly lower than in

the saturation case. The collector to emitter voltage (V_{CE}) will typically be a few volts, so the base-collector junction will be reverse biased by this value minus V_{BE}.

If a transistor used as a switch ends up in the active region, its power dissipation may be excessive. The reverse active region is not commonly used but does have some applications in some types of logic and analogue switching circuits.

From Fig.1a and Fig.1b it is clear that most of the supply voltage will appear across the load *if* the transistor is saturated. In saturation, the collector to emitter voltage across a bipolar transistor does not vary much with varying collector current, so we apply a more or less constant voltage to the load, which is usually what we want.

The properties of a transistor in saturation are different from those in the

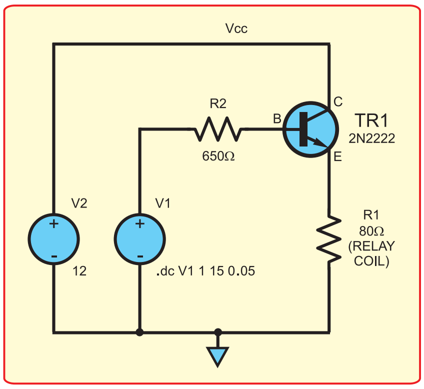


Fig.2. Circuit used to simulate Fig.1a, using LT spice from Linear Technology

active region of operation, and we need to be careful about applying familiar assumptions about transistor operation. An important characteristic of the transistor in the forward active region is the current gain, or strictly speaking the *forward current gain*. This is the familiar transistor 'gain' and has the symbol β (or β_F) or h_{FE}. In the forward active region the collector and base currents are related by the well known relationships

$I_C = \beta I_B$ and $I_B = I_C / \beta$

These are simple and useful equations, but they **do not apply in the saturation region**. For a transistor in saturation the base current is greater than I_C/β. In fact, the base current exceeding I_C/β can be regarded as a condition for saturation. The value of I_C/I_B in saturation is called the forced beta, β_{FOR}.

An example will clarify how we make use of these ideas. We want to use the circuit in Fig.1b (the one that we know works) to supply 150mA to the relay using a suitable transistor (in terms of current rating).

Assume the transistor has a typical gain of 100 (ie β = 100), and that the base drive is 5V. We might proceed as follows. If we use $I_B = I_C/\beta$ we get I_B = 0.15/100 = 1.5mA. If we assume that V_{BE} is 0.7V to get 1.5mA base current we need R_B=*V*/*I*=(5-0.7)/0.0015=2.9kΩ. Note that this is much larger than the actual resistor used.

The problem with using a 2.9kΩ in the base is that transistor gain is actually quite variable, under different conditions (current, temperature) and importantly between individual transistors. So, our assumption that the gain is 100 is likely to be wrong. If the gain was actually 70 we would only get approximately 105mA through the relay, corresponding to 8.4V across its 80Ω; which might be less than the 'pull-in voltage'. The assumption that collector-emitter voltage is very small would also be wrong; it would actually be about 3.6V, resulting in relatively large transistor power dissipation.

Forced saturation

Let's look at the same circuit again, but this time making sure the transistor is in saturation. Unlike the actual beta we can choose a forced beta, let's say five times smaller than the nominal value, that is $\beta_{FOR} = I_C/I_B = 20$. So, with all else the same as above we need a base current of 7.5mA (150mA/20) for which R_B = *V*/*I* = (5-0.7)/0.0075 = 573Ω. Note that this value is similar to the one used for the base resistor Fig.1b.

Now, if our transistor gain is 70 rather than 100 we still get 7.5mA in the base, 150mA through the relay and a small collector-emitter voltage. The forced beta is only 3.5 times less than the actual beta, rather than five times as we designed, but the factor of five has given us some 'margin for error' in making sure the transistor is saturated. In addition to guarding against problems with variable transistor gain, a low forced beta also makes the circuit able to cope with reasonable variations in load resistance.

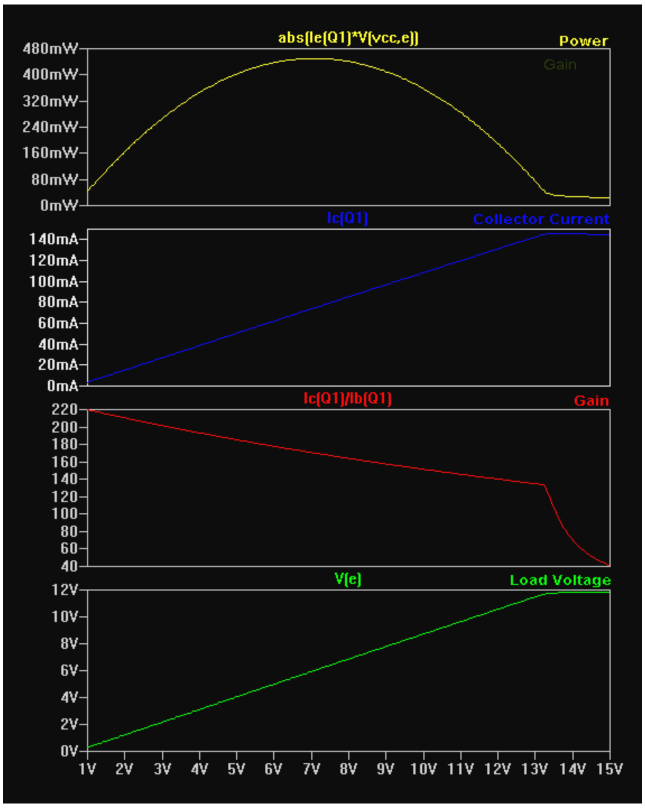


Fig.3. Simulation results from the circuit in Fig.2, with a DC sweep from 1V to 15V on the base drive voltage

Returning to the more problematical circuit in Fig.1a, and assuming the transistor is on and that there is around 4.3V across the load, it follows that the collector-emitter voltage is about 7.7V (12–4.3); we conclude that the transistor is in the forward active region. So, in addition to insufficient load voltage (across the relay), the transistor is not operating optimally for switch use. This calculation has not taken account of the voltage drop in the base resistor, the transistor's gain, or the possible variation in V_{BE} (it will not be exactly 0.7V), so the voltage on the load will not be exactly 4.3V.

We can estimate the load voltage a little better (although still only approximately) if we know the transistor's gain. Lets assume β=100 to illustrate this. The total voltage across the relay (load, R_L), the base-emitter junction of the transistor (V_{BE}) and the base resistor (R_B) is equal to base drive voltage (V_{IN}), so

$$V_{IN} = \beta I_B R_L + V_{BE} + I_B R_B$$

Where I_B is the base current. We do not know an exact value for V_{BE} and to get an accurate calculation we would need to consider the exponential relationship between V_{BE} and the collector current, and also the effect of V_{CE} on the collector current (the Early effect). However, an approximate value is fine to check what is happening in the circuit and we can use two values for V_{BE} of 0.6 and 0.8 and look at a range of resulting values for I_B and hence load currents and voltages.

Putting β = 100, V_{IN} = 5V, R_B = 650Ω and R_L = 80 Ω in the above equation gives us

$$5 - V_{BE} = 8650 I_B$$

So, if V_{BE} = 0.6 we get I_B = 510μA, so the load current is about 51mA; and with V_{BE} = 0.8 we get I_B = 490μA, so the load current is about 49mA; the voltages across the load are 4.1V and 3.9V respectively, which is just less than 4.3 volts, as expected.

With around 8V across the transistor and around 50mA of current flowing it will be dissipating about 400mW. Compare this with the situation in Fig.1b when the load is on, we will have (say) about 0.2V across the transistor (V_{CEsat}) and 150mA flowing, giving a power dissipation of about 30mW.

In summary, the problems with the circuit in Fig.1a (in the on state) are that the load voltage is too low, the transistor is not saturated, which it should be in a good switch, and consequently the power dissipation of the transistor is much higher than it needs to be. It is not impossible to use this configuration to switch a load, but we need to apply a base drive voltage which will saturate the transistor.

When a transistor is saturated, both junctions are forward biased. To achieve this in the circuit in Fig.1a we need a base drive voltage above 12V. We can investigate

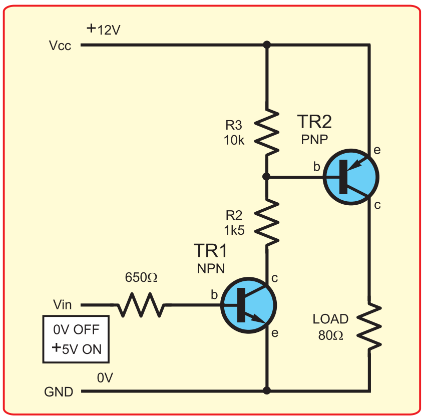


Fig.4. Using two transistors to switch a grounded load (ie, relay) using a control voltage less than the load

what happens as the base drive voltage is changed using a circuit simulator. We can perform a DC sweep analysis, varying the input voltage between chosen limits in suitable steps to produce graphs of circuit parameters (eg collector current) against base drive voltage.

Circuit simulation

To simulate the circuit it helps to choose a real transistor; we do not know which transistor Noel used, so we will make an arbitrary choice of the 2N2222. Using a Philips 1997 datasheet for the 2N2222 we can check some of the transistor's characteristics:

V_{CEmax} 30V

I_{Cmax} 800mA

P_{tot} (maximum dissipation) 500mW

$\beta(h_{FE})$ ranging from 35 to 300 depending on I_C and V_{CE}

V_{CEsat} 0.4V at 150mA

These seem to be OK for the circuit we are using.

To simulate the circuit we used LTspice, which is available from Linear Technology (see **http://www.linear.com/designtools/software/**). It is enhanced for switching regulator simulation, but is readily usable for other circuits.

The schematic used for the simulation is shown in Fig.2. The DC sweep of the base drive went from 1V to 15V in 0.05V steps. The resulting graphs are shown in Fig.3.

In Fig.3 we have graphs for the power dissipation (yellow), collector current (blue), transistor current gain (red) and load voltage (green). The power and gain values are calculated using waveform expressions.

Looking at all the waveforms we see a distinct change at around 13V. This is the point the transistor changes from being in the active region to being saturated. The power dissipation is low once the transistor saturates despite the high base drive voltage and high collector current. Once the transistor saturates the collector current does not change much. It remains at around 150mA, which is the same as the load current we calculated for the circuit in Fig.1b.

The gain of the transistor falls significantly in saturation; this occurs as it

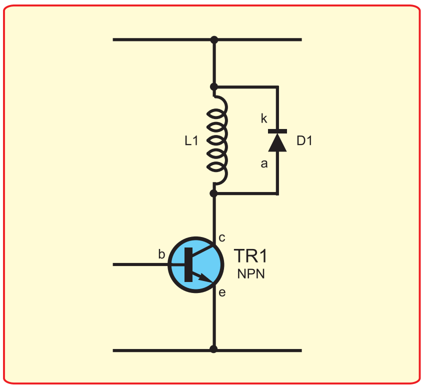


Fig.5. Using a diode to protect a transistor switching an inductive load

moves from active gain (with a β of around 200) to much lower forced beta values. The voltage across the load is just under 12V when the transistor saturates because only the small V_{CEsat} is dropped across the transistor.

The circuit in Fig.1a can be described as a *high side NPN switch*. It can be used as an effective switch, but has the disadvantage of requiring a voltage above the load supply voltage to control switching. If the load must be grounded, an alternative is to use a *PNP* transistor in common-emitter configuration (the *PNP* version of Fig.1b); however, this still requires a switching voltage which goes up to 12V (to switch the transistor off) and so cannot be controlled using a 0 to 5V signal.

A two-transistor circuit using an *NPN* transistor to control a *PNP* device can be used to switch a 12V grounded load from a 5V control signal. An example of such a circuit is shown in Fig.4. The component values given should drive the transistors into saturation, with forced betas of around 20 for the 80Ω load shown. For different applications, different resistor values may be needed.

Protection

One other thing we should mention about these circuits is the need to protect the transistor from back-EMF generated in the relay coil. When current in an inductive load, such as a relay or solenoid, is switched off, the magnetic field, which had been established by the supplied current, collapses. This induces a reverse (opposite to applied) voltage known as the 'back EMF' or inductive kick.

For example, in the circuit in Fig.1b, the back-EMF appears as a positive voltage spike at the collector of the transistor. This may result in voltages large enough to damage or destroy the transistor used to switch the load. The more rapid the change in current as the inductor is switched off, and the larger the inductor value, the greater the back-EMF generated.

The usual method of preventing the back EMF from causing problems is to place a diode (variously called the freewheeling diode, flyback diode or snubber diode) across the inductor, as shown in Fig.5. The term 'clamped inductive load' is also used in this situation. This diode is reverse biased when the power switching device is on, but is forward biased by the back-EMF; so the diode dissipates the power or feeds it back to the power supply.

Recycle It!

BY JULIAN EDGAR

The good bits in old receivers

Looking for a cheap voltmeter or current meter to build into a power supply or some other project? A discarded receiver can often supply the parts required.

I'LL BE straight-up with you – most old receivers don't yield a bonanza of goodies. Rather, they're a source of a handful of good bits. Some, like the high-value capacitors from the power supply, can be put aside for later projects, while others, like the fuses and machine screws, can find a home in your parts drawers.

Sometimes, there are also a few heatsinks worth salvaging – and at other times, the speaker output terminals are useful. But to be honest, many hum-drum receivers aren't worth the salvage effort.

There's one main exception to that rule: if the receiver has an analogue centre-tuning meter for FM reception, an analogue signal strength meter or a bargraph-style LED power output meter, grab it. Why? – we'll come to that in a moment.

Another thing to look for when checking out old receivers is the rear panel marking for total power consumption. If it's in the hundreds of watts, you're probably dealing with a high-quality design. And that makes it more likely that some of the parts will be worth salvaging.

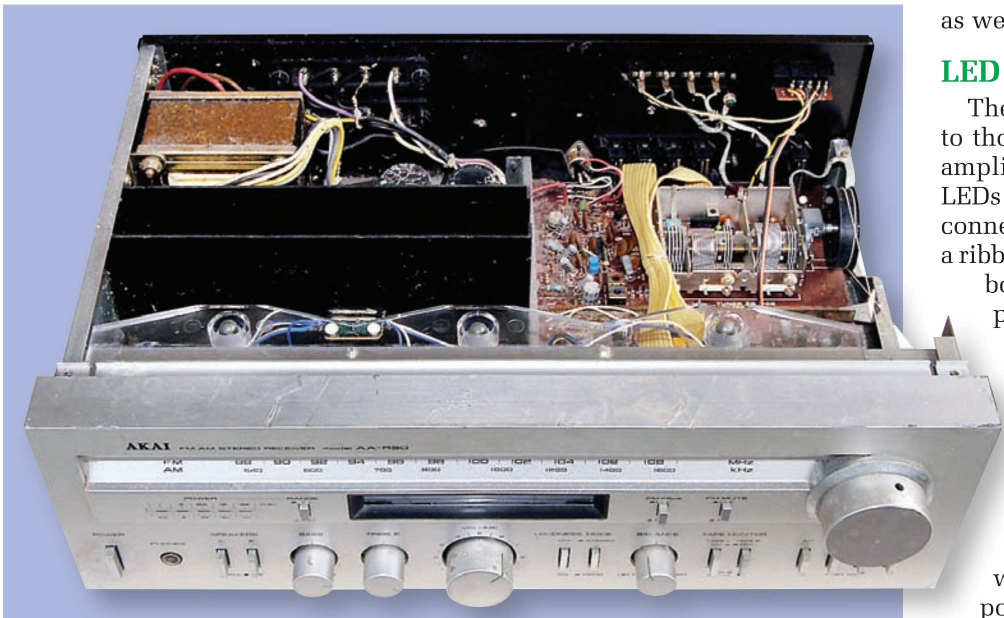
Bits and pieces

The Akai receiver pictured here (a model AA-R30 from the early 1980s) had seen much better days. The front panel was corroded and there were several gouges in the other panels. The lower panel was also badly dented – probably from when it was thrown on the tip.

I bought it for just £5, but it's the sort of receiver that's often given away at garage sales or put out for kerbside rubbish collections.

Leaving aside the meters and displays for a moment, after spending about half an hour with a pair of side cutters and a Philips-head screwdriver, I ended up with four knobs, four fuses, the nuts and washers from four potentiometers (you know how hard these are to source), three low-voltage bulbs, two 8200μF 40V capacitors and a large folded U-shaped aluminium sheet that was used as a heatsink.

OK, so those parts are not really worth the effort unless you like pulling things apart. But let's go back to the displays – these really are useful, as we shall see.



This Akai unit is typical of 1980s receivers that are now often thrown away. When looking for a worthwhile receiver to salvage, look for the presence of digital and analogue meters – they're very useful in lots of applications.

LED bargraph display

The output power meter is similar to those used in many receivers and amplifiers of the era. It consists of five LEDs mounted on a PC board that's connected to another small board via a ribbon cable. Importantly, these two boards comprise the whole of the power meter, which makes it easy to remove for re-use.

With this type of design, it's also straightforward to identify what wires do what. In fact, before you're too free with the cutters, look closely at where the wires go.

In this case, there were two wire pairs that went from the power meter sub-board to the main board. They comprised almost certainly: (1) power and ground; and (2) the signal inputs to the display (ie, the

signal that causes the LEDs to light in sequence).

It wasn't hard to figure out which was which, as the main board had 'Speaker A' and 'Speaker B' designations next to the connections for the white and purple wires – so these were the signal inputs. The other pair of wires (yellow/black) were therefore the power supply leads, with black almost certainly the negative (ground) connection.

To verify this, I connected a variable power supply to the supply leads and slowly wound up the voltage. At the same time, I fed a small DC voltage to one of the signal inputs. And it worked, the first LED coming on at 0.9V on the signal input (either Speaker A or Speaker B) and with a 6V supply. Similar LED bargraphs are used in many cassette decks – again, they're easy to salvage and hard to kill.

On-board controls

In the case of the Akai power meter, some on-board controls were also provided.

First, a pushbutton switch changed the display to read either x1 or x0.1 of full scale (which, as it happened, was marked at 38W). In addition, each input channel had a preset potentiometer mounted on the PC board for fine tuning. By adjusting the presets and/or the pushbutton, it was possible to set the full-scale deflection to anything between 3.4V and 18.4V.

Further testing showed that while the response of the five LEDs wasn't perfectly linear, it wasn't far off.

So what good is this display? Well, it's ideal anywhere you need an indication of DC voltage!

Voltmeter and ammeter

The two analogue meters (one for signal strength and the other for tuning) on the old Akai receiver are even more useful. These are both contained in the one housing and are ideal for showing both current flow (positive and negative) and voltage. The application? – anywhere a battery is charged and discharged, as in a solar-powered battery bank or in a low-voltage electric vehicle with regeneration.

The signal-strength meter is easily converted to read a voltage from 3.4V upwards – simply wire a 1MΩ potentiometer in series with it, and adjust the pot to give the required full-scale deflection – see Fig.1.

In this case, we've salvaged just the heatsink, some knobs, fuses, screws, pot nuts and washers, some filament bulbs, the power supply capacitors and the dual analogue meters.

MAKING A VOLTMETER

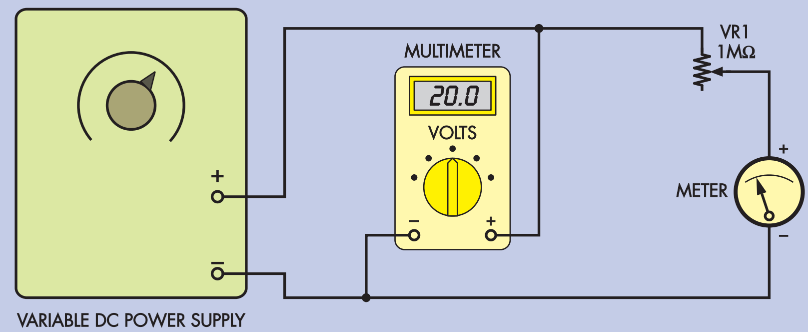


Fig.1: here's how to recalibrate the signal-strength meter so that it can be used to measure higher voltages. All you need is a 1MΩ potentiometer, a variable power supply and a multimeter. The pot is used to set the full-scale deflection voltage, while the variable supply and multimeter allow the meter to be calibrated.

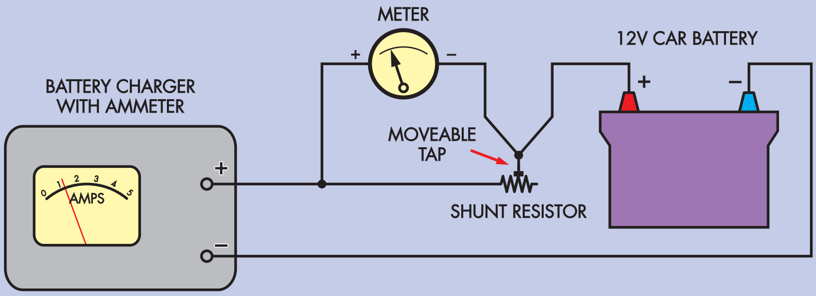


Fig.2: this circuit shows how to convert and calibrate the tuning meter for use as a current meter. The shunt resistor (easily made from fencing wire) is wired in parallel with the tuning meter, and its effective length adjusted until the reading on the meter agrees with the reading on the ammeter.

The receiver's signal and tuning meters can easily be adapted to show voltage and current. This photo shows the signal/tuning meter combination equipped with the new scales, while in the foreground is the ammeter shunt, made from a length of salvaged stainless steel rod taken from a discarded garden leaf rake. This set-up is ideal for monitoring a battery bank (eg, in a solar panel installation).

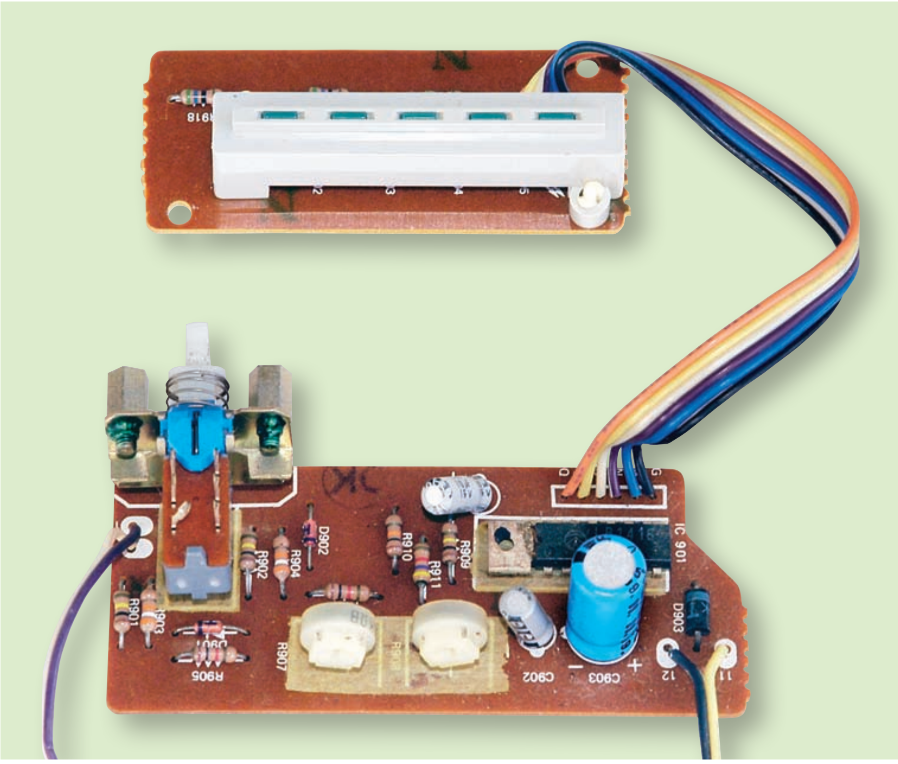
The tuning meter can be converted to a current meter simply by placing a shunt in parallel with it. A shunt is easily made from steel fencing wire or, as I did, from a length of stainless steel rod salvaged from a garden rake!

It's also easy to make new scales for the meters using a PC, scanner and printer – see *Recycle It!* for Feb '09. To calibrate the signal-strength voltmeter, you will need a variable power supply. Set the full-scale deflection with the pot and then calibrate the markings against the input voltage as measured by a multimeter (see Fig.1).

Calibrating the ammeter is only slightly more difficult. Fig.2 shows the basic scheme. In this case, a high-powered battery charger (complete with built-in ammeter) was connected to a flat car battery. The shunt was inserted in series between the charger and the battery and the tuning meter (now acting as an ammeter) wired in parallel with the shunt.

By sliding one terminal along the shunt (effectively altering its length and thus its resistance), the reading on the new ammeter can be calibrated to match the battery charger's ammeter. If the battery charger has a two-position charging switch (ie, to alter the charging rate), it's a good idea to check the meter calibration at the two different charging current values. Alternatively, you can use a current clamp to measure the current flow and then place varying loads on the battery.

So there you are – any salvaged receiver will give you a handful of useful parts. And if you get hold of a receiver with analogue or digital meters, it takes relatively little effort to convert the meters for use in a wide range of applications. ***EPE***



Many older receivers, amplifiers and cassette decks use LED bargraph meters. In this case, the meter's electronics are completely separate from the main PC board, making it easy to salvage and use in another application. Note how only two pairs of wires connect to the sub PC board at bottom – one pair for the power supply connections and the other pair for signal inputs. This particular circuit also uses two trimpots and a high/low switch. With these adjustments, it was easy to set the full-scale deflection to anywhere between 3.4V and 18.4V. That makes it a pretty useful voltage meter for use in all sorts of applications.

Rat It Before You Chuck It!

Whenever you throw away an old TV (or VCR or washing machine or dishwasher or printer) do you always think that surely there must be some good salvageable components inside? Well, this column is for you! (And it's also for people without a lot of dough.) Each month we'll use bits and pieces sourced from discards, sometimes in mini-projects and other times as an ideas smorgasbord.

And you can contribute as well. If you have a use for specific parts which can easily be salvaged from goods commonly being thrown away, we'd love to hear from you. Perhaps you use the pressure switch from a washing machine to control a pump. Or maybe you salvage the high-quality bearings from VCR heads. Or perhaps you've found how the guts of a cassette player can be easily turned into a metal detector. (Well, we made the last one up but you get the idea . . .)

If you have some practical ideas, write in and tell us!

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Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

THE previous article in this series covered modern ways of producing labels for front panels, and methods for making complete front panel overlays. This is largely the end of the story when using a labelling machine to produce panel legends. The labels obtained are self-adhesive and very durable, so it is mostly just a matter of getting them positioned accurately and pressing them into place, but there are a few points worth bearing in mind.

Cutting down

A definite drawback of some electronic labellers in the current context is that they use relatively wide tapes, and consequently produce lettering that is often a bit larger than would be ideal. The simplest labellers can only use one size of tape, which is usually 9mm or 12mm. On the face of it, even the 9mm type will produce lettering that is too large for most projects.

However, the actual height of normal text is much less than the width of the tape, and is typically only about 4mm or so. This is just about right for most projects, but there is often an option to print smaller text.

Most modern labellers will accept tapes of several different widths, and one that can use 6mm, 9mm, and 12 mm tapes is perfect when making labels for projects. The actual height of standard lettering on a 6mm tape is fractionally less than 3mm, which makes it just about right for small projects. There are actually 3.5mm tapes, and with a suitable labeller these can be used to produce labels for even the smallest of projects. The 9mm tapes are useful when labelling medium-sized and large projects, and the 12mm type are handy for even larger labels, such as when naming a project (‘Logic Tester’, ‘Emergency Lighting Unit’, or whatever).

Labellers have a built-in cutter that produces neat results, but the labels often have a substantial blank area around the lettering. The raw labels tend to look ‘not quite right’ when used with larger projects, and the wide border can make it difficult to find sufficient space for them on small projects. Consequently, it is often necessary to trim the labels slightly in order to produce something that is a bit more usable. This can be rather fiddly, especially with the 6mm tapes, but with due care it can be done with the aid of a sharp modelling knife, a cutting mat, and a metal ruler, or with a paper trimmer.

The labels normally use an adhesive that does not permit them to be slid into exactly the right position, but you do not necessarily have to get it right first time. Provided a label has not been fully pressed down into place, it is usually possible to carefully peel it off and try again. If necessary, replacing one that has become damaged during the placement process takes little time and costs next to nothing.

Whenever individual labels are used, it can be helpful to mark guide lines or use tape to provide a guide that will make it easier to get a row of labels aligned accurately. Of course, the guide lines must be marked using a method that makes them reasonably easy to remove, and which does not damage the front panel.

Panel legends made using a labelling machine are perhaps slightly less professional looking than those produced using the old method of rub-on transfers. On the other hand, they are far more durable than legends produced using transfers, which tend to rub off almost as easily as they rubbed on! It is not normally necessary to use any form of protective covering unless the project will be left outside in the elements for long periods, or it will receive a lot of rough treatment for some other reason.

Hard copy

Using a computer and a printer to produce labels and panel overlays has the advantage of making just about anything possible. However, matters tend to be less straightforward than using a labelling machine when it is time to print out the hard copy and add it to the panel.

There are the problems of finding suitable media for the hard copy, gluing everything in place securely without damaging anything, and obtaining durable results that will continue to look good for a reasonable period of time. Unfortunately, it is likely that none of these criteria will be met if you simply print out designs using plain paper, and then glue them in place using the first adhesive that comes to hand.

Durability is dependent on the type of paper used and on the type of printer. A laser printer has definite advantages, with the main one being that the printing process does not use inks. Toner powder and a thermal printing process are used, which means that there are no inks to run if the panel gets damp.

A laser printer will also give high quality results using practically any paper. It is also possible to make high quality printouts onto a suitable grade of transparent plastic film. Only use plastic media that is specifically designed for use with a laser printer, because the heat of the printing process can melt some plastic sheet material, possibly ruining the printer in the process.

The main drawback of laser printers is their relatively high cost. Prices have fallen in recent years, but they remain relatively expensive, and in the case of the colour type they also have very high running costs. Inkjet printers are by far the most popular type of printer at present, and they can produce high quality results in colour or in black and white with reasonable running costs.

However, they are not at their best when using ordinary copier paper or something of this ilk. It is also unlikely that ‘run of the mill’ paper will give long-lasting results. Another problem with plain paper is that it tends to be quite thin and absorbent, which can give problems with adhesive applied to the reverse side of the paper, producing stains on the front side.

In order to get the best results with an inkjet printer it is important to use a paper that is specifically designed for this type of printing. In the current context, one that is fairly thick and has a gloss or semi-gloss finish is likely to give the best looking and longest lasting results. Using a thick paper helps to avoid problems when gluing the overlay in place, and papers that have something like a gloss or satin finish are generally less prone to problems with finger marks.

Media coverage

In order to obtain a really tough finish it is necessary to give panel overlays a transparent covering of some sort. The simplest way of

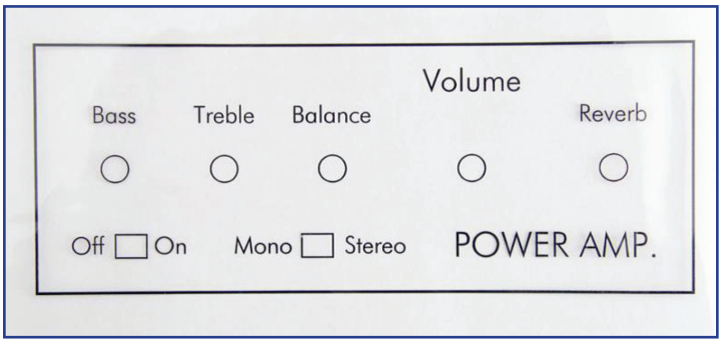

Fig.1. This panel overlay has been printed onto transparent film as a ‘mirror image’, but here it is viewed from the ‘wrong’ side, so that the correct image is obtained. When fixed to a panel, the printing is protected by the plastic base material and is virtually scratch-proof

achieving this is to use a transparent lacquer or varnish, but there is a potential problem when using this method with an overlay produced using an inkjet printer. The ink has a tendency to run into the varnish if it is applied using a brush. It is, therefore, better to use a spray-on varnish, applying it sparingly in several thin coats, rather using one or two heavy applications.

It is possible to obtain spray-on coatings intended specifically for protecting inkjet prints. One of these used in accordance with the maker's instructions should provide good results.

The alternative approach, and the one that is likely to give the most durable results, is to cover the overlay with a transparent plastic material. The simplest and cheapest way of achieving this is to use one of the sheets of self-adhesive transparent plastic materials that can be obtained from the larger stationers. Using a thicker gauge material makes it easier to avoid problems with creases and air bubbles and provides better protection.

Unfortunately, only the thinner grades seem to be readily available these days, so it is essential to proceed carefully and get it right first time. Peeling back so that another attempt can be made is likely to damage the surface of the overlay.

Probably the best approach is to start with a slightly oversize piece of material, start applying it at one end of the panel, and then carefully press it down into place as it is spread across the panel. Any small bubbles can be removed by bursting them with a pin and pressing the covering down onto the panel. The excess material around the edges of the panel is then trimmed away to give a neat finish.

There used to be a method of producing high quality overlays by printing a mirror image of the design onto transparent plastic using a simple photographic technique. The overlay was then glued to the panel with the printed side against the panel. The overlay was therefore viewed from the 'wrong' side, giving a right-way-round image that was protected by the transparent plastic base material. This method provides very impressive looking results and the ultimate in durability.

Computer printout

Essentially the same method can be used with an overlay produced using a computer and a printer (Fig.1). As pointed out previously, laser printers can be used with some types of transparent sheet material. Inkjet printers are less accommodating, and the inks tend to run if they are used with ordinary plastic sheets.

It is possible to obtain special sheets which have a coating that absorbs the ink and prevents it from running. These are relatively expensive and difficult to obtain, but should provide excellent results.

There is a potential problem in printing a mirror image of the overlay. There might be an option to do this in the printer or page settings, but if not, most graphics programs can 'flip' or 'mirror' the image (Fig.2).

The choice of adhesive is important, as some types of glue will produce blotchy or noticeably discoloured results. Some might attack the surface of the printout, or even the panel itself if it is made from plastic.

Scotch Spray Mount is not cheap, but if used correctly it provides excellent results in this application. It enables the overlay to be removed and repositioned if you do not get it right the first time.

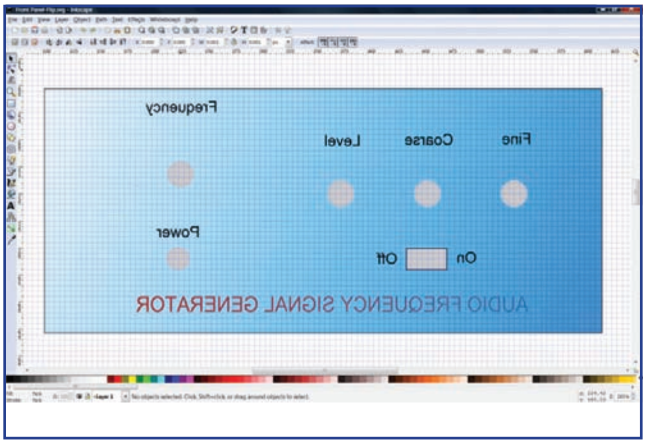

Fig.2. Most graphics program can flip or mirror the drawing. In this case it was necessary to first select every element in the drawing, and then the Flip Horizontal command was used to convert the drawing to a 'mirror image'

Printer settings

When making printouts of panel overlays there can sometimes be a problem with scaling. There is almost certainly an error in the printer or page settings if the overlay is very much larger or smaller than the panel it is supposed to fit. The exact facilities on offer are dependent on the particular application program and printer in use. The default size setting is sometimes one that fits the printout to be as large as possible without anything being lost off the edge of the page. This option is usually called something like 'Scale to fit'. In this case, it is an actual size printout that is needed, so the size or scale setting should be at 100%. Make sure that any scaling options that could override this setting have been deselected.

Remember that an ordinary A4-size printer can handle a maximum width of 210mm, and this assumes that borderless printing is used. In practice, it is advisable to use a maximum width of about 200mm. Switching from landscape to portrait printing results in the design being printed vertically instead of horizontally, and increases the absolute maximum size to slightly less than 300mm. This is more than adequate for the vast majority of projects. An A3 printer gives an absolute maximum length of 420mm, although most A3 inkjet printers will actually take the slightly larger A3+ paper size, which can accommodate panels up to about 500mm on their longest dimension.

A small error in the scaling could be due to a mistake in the page or printer settings, or it could be caused by a lack of precision in the software. Experience suggests that application software and printer drivers usually provide a high degree of accuracy when printing to scale, but there can be occasional problems. There might be a software update that will cure the problem, but in some cases it is necessary to adjust the scaling slightly in order to 'fine tune' the size of the printout.

This will probably require a bit of experimentation, but it should be possible to get things spot-on. It should only be necessary to go through this process once. Having found the right scaling figure for one drawing, that figure should give accurate results when applied to any other drawing.

It is often possible to adjust the scaling via the page setup facility or in the printer settings (Fig.3). If not, it will probably be possible to scale the drawing up or down slightly prior to printing it.

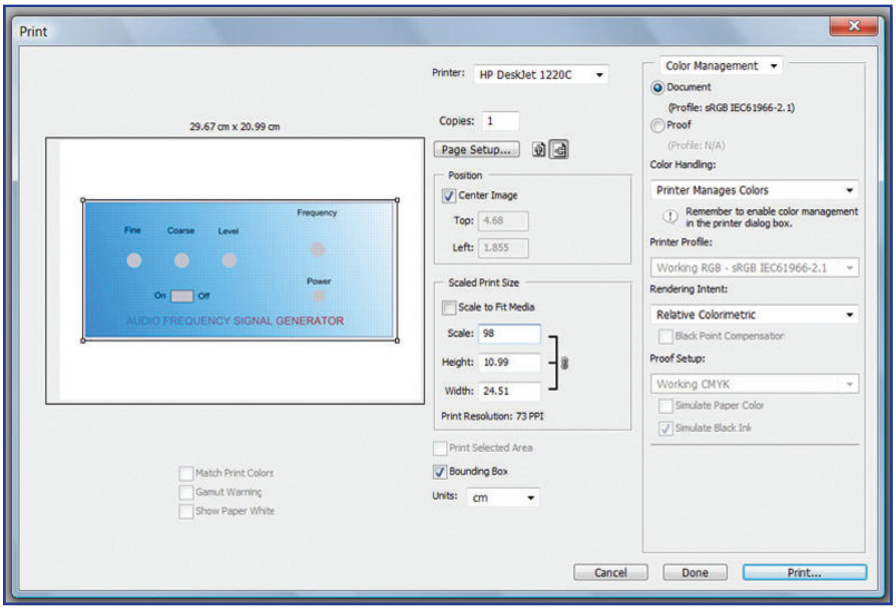

Fig.3. The printer settings often include various controls for adjusting the size of the printed image. In this case, there is a scaling control that enables the printout to be scaled up or down slightly, should this prove necessary

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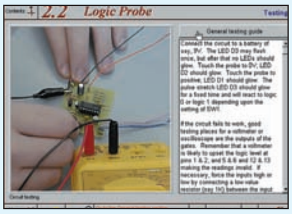
ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS

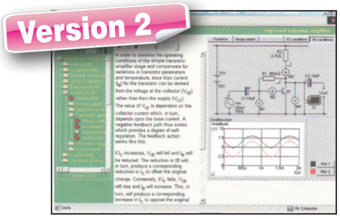


Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture, circuit simulation** and **p.c.b. design** software is included.

The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ELECTRONIC CIRCUITS & COMPONENTS V2.0

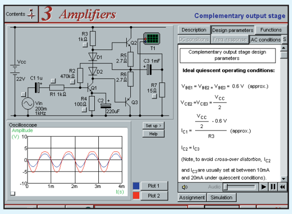


Circuit simulation screen

Electronics Circuits & Components V2.0 provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals***: units and multiples, electricity, electric circuits, alternating circuits. ***Passive Components***: resistors, capacitors, inductors, transformers. ***Semiconductors***: diodes, transistors, op amps, logic gates. ***Passive Circuits. Active Circuits***. *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.

Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS

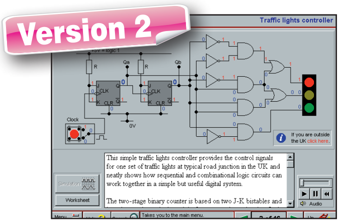


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

Sections on the CD-ROM include: ***Fundamentals*** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). ***Op Amps*** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. ***Amplifiers*** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). ***Filters*** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). ***Oscillators*** – 6 sections from Positive Feedback to Crystal Oscillators. ***Systems*** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0



Virtual laboratory - Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (above), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.

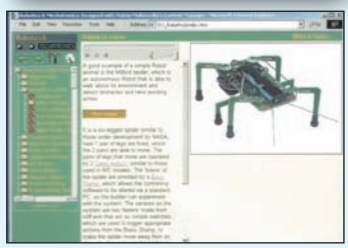
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

ANALOGUE FILTERS

Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ROBOTICS & MECHATRONICS


Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:
(Order form on third page)

Hobbyist/Student	£44	inc VAT
Institutional (Schools/HE/FE/Industry)	£99	plus VAT
Institutional 10 user (Network Licence)	£249	plus VAT
Site licence	£499	plus VAT

(UK and EU customers add VAT at 15% to 'plus VAT' prices)

PICmicro TUTORIALS AND PROGRAMMING

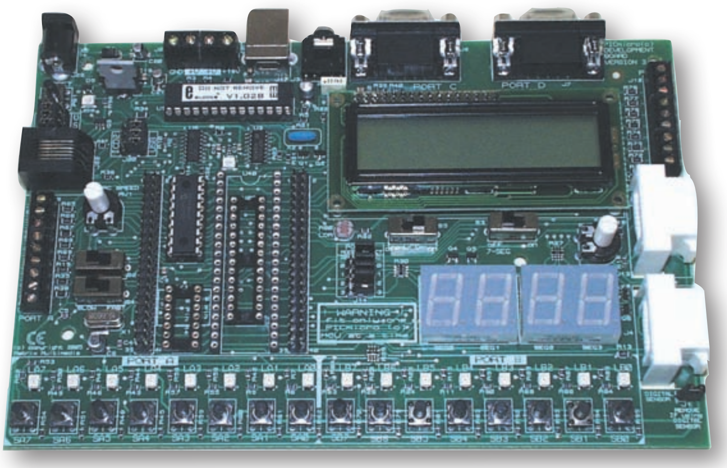
HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)



£155 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

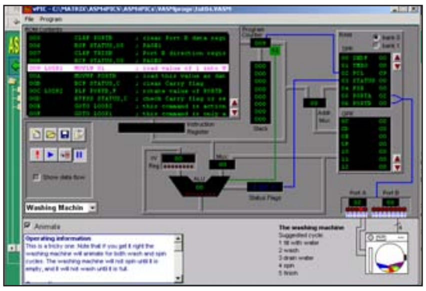
ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

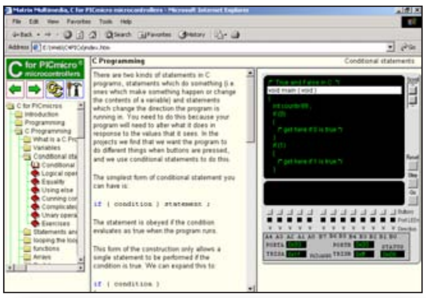


'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

FREE with Flowcode V4 (student and institutional versions) ECIO board – a 28-pin reprogrammable microcontroller.

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols ● Full on-screen simulation allows debugging and speeds up the development process.

● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 18, 28 and 40-pin devices ● 16-bit arithmetic strings and string manipulation ● pulse width modulation ● I2C. New features of Version 4 include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)

PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

(UK and EU customers add VAT at 15% to 'plus VAT' prices)

Hobbyist/Student	£44	inc VAT
Institutional (Schools/HE/FE/Industry)	£99	plus VAT
Institutional/Professional 10 user (Network Licence)	£350	plus VAT
Site Licence	£699	plus VAT
Flowcode Institutional (Schools/HE/FE/Industry)	£149	plus VAT
Flowcode 10 user (Network Licence)	£399	plus VAT
Flowcode Site Licence	£799	plus VAT

SPECIAL PACKAGE OFFER

TINA Pro V7 (Basic) + Flowcode V3 (Hobbyist/Student)

TINA Analogue, Digital, Symbolic, RF, MCU and Mixed-Mode Circuit Simulation, Testing and PCB Design

£57.00 inc. VAT and p&p

TINA Design Suite is a powerful yet affordable software package for analysing, designing and real time testing analogue, digital, MCU, and mixed electronic circuits and their PCB layouts. You can also analyse RF, communication, optoelectronic circuits, test and debug microcontroller applications.

Enter any circuit (up to 100 nodes) within minutes with TINA's easy-to-use schematic editor. Enhance your schematics by adding text and graphics. Choose components from the large library containing more than 10,000 manufacturer models. Analyse your circuit through more than 20 different analysis modes or with 10 high tech virtual instruments. Present your results in TINA's sophisticated diagram windows, on virtual instruments, or in the live interactive mode where you can even edit your circuit during operation.

Customise presentations using TINA's advanced drawing tools to control text, fonts, axes, line width, colour and layout. You can create, and print documents directly inside TINA or cut and paste your results into your favourite word- procesing or DTP package.

TINA includes the following Virtual Instruments: Oscilloscope, Function Generator, Multimeter, Signal Analyser/Bode Plotter, Network Analyser, Spectrum Analyser, Logic Analyser, Digital Signal Generator, XY Recorder.

***Flowcode V3** (Hobbyist/Student) – For details on Flowcode, see the previous page.*

This offer gives you two seperate CD-ROMs – the software will need registering (FREE) with Designsoft (TINA) and Matrix Multimedia (Flowcode), details are given within the packages.

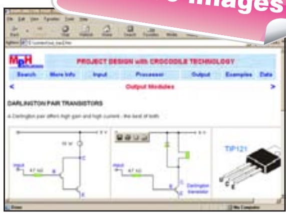
Get TINA + Flowcode for a total of just £57, including VAT and postage.

PROJECT DESIGN WITH CROCODILE TECHNOLOGY

An Interactive Guide to Circuit Design

Over 150 pages Over 600 images

An interactive CD-ROM to guide you through the process of circuit design. Choose from an extensive range of input, process and output modules, including CMOS Logic, Op-Amps, PIC/PICAXE, Remote Control Modules (IR and Radio), Transistors, Thyristors, Relays and much more.
Click Data for a complete guide to the pin layouts of i.c.s, transistors etc. Click More Information for detailed background information with many animated diagrams.
Nearly all the circuits can be instantly simulated in Crocodile Technology (not included on the CD-ROM) and you can customise the designs as required.*



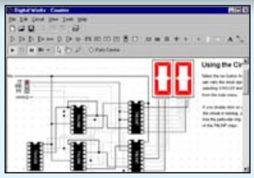
WHAT'S INCLUDED
Light Modules, Temperature Modules, Sound Modules, Moisture Modules, Switch Modules, Astables including 555, Remote Control (IR & Radio), Transistor Amplifiers, Thyristor, Relay, Op-Amp Modules, Logic Modules, 555 Timer, PIC/PICAXE, Output Devices, Transistor Drivers, Relay Motor Direction & Speed Control, 7 Segment Displays.Data sections with pinouts etc., Example Projects, Full Search Facility, Further Background Information and Animated Diagrams.
Runs in Microsoft Internet Explorer
All circuits can be viewed, but can only be simulated if your computer has Crocodile Technoloy version 410 or later. A free trial version of Crocodile Technology can be downloaded from: **www.crocodile-clips.com. Animated diagrams run without Crocodile Technology.*

Single User £39.00 inc. VAT.

Multiple Educational Users (under 500 students) £59.00 plus VAT. Over 500 students £79.00 plus VAT.
(UK and EU customers add VAT at 15% to "plus VAT" prices)

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

DIGITAL WORKS 3.0



Counter project

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READOUT

Email: editorial@wimborne.co.uk

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly

★ LETTER OF THE MONTH ★

Simplifying the anemometer project

Dear EPE

I have just finished reading the August 2009 *Recycle It!* article about constructing an anemometer from salvaged parts. Purely by coincidence, I had a salvaged VCR head sitting on my desk, having pulled it out of a binned machine several months ago. It had been parked there ever since, mostly just because I like the look of it. (well, it is shiny – irresistible to the true pack-rat...)

So, I picked up the head and started poking around at it and was struck by the fact that in its original configuration this gizmo was 'driven', ie, it has a motor in it. And what do we get when we back-drive a motor? – yes, a generator! A bit more investigation revealed the presence of two phases of windings; and, by coupling them together I was able to measure something in excess of 3V, just from giving the rotor a good hard spin by hand.

I have not had time to go any further with this, but it seems to me that the anemometer project could probably be reduced to the following:

1) Fit wind cups to the top of the VCR head

2) Break the tracks on the head's PCB where they connect to the motor's coils

3) Connect up the coils in whichever phasing gives the largest output voltage (I just measured with my DMM, set on 'AC volts').

4) Connect the motor coil output to a display meter. This will require some fiddling around to get a usable range of movement on the meter, but I expect nothing more than a couple of resistors will be needed. It might also be beneficial to add an RC circuit on the motor output – just to smooth its output

5) Package as necessary

Of course, I'm not denigrating the original article as published – it's a very ingenious lash-up in its own right, and I plan to keep the 'mouse-as-rotation/RPM-detector' idea in my mental file for future reference. But when I started looking at that VCR head, it suddenly occurred to me that the anemometer could be simpler... 'much' simpler!

Anyway, thanks – as a long-time pack-rat, I love the *Recycle It!* articles.

Mike Henders, Canada, by email

Many thanks Mike, while I certainly think your approach would work I do have my doubts about the linearity (and hence accuracy) of the simpler set up which you are proposing. That said, there's only one way to find out... build one! Do any readers have experience of using these devices for measuring angular speed?

Feedback and questions…

Dear EPE

I have been reading *EPE* for a number of years and would like to congratulate you on exploring the more difficult aspects of filter circuits in your last few issues. I think this has really enhanced your market and image to those who already have a good background, but need to understand some of the finer details (including the mathematics) and wish to keep on learning.

I do hope you can keep this up in forthcoming issues. For example, it would be good if you could demonstrate some concepts (decibel reduction, and resulting cut-off ripples impacting on signals) via some practical circuits. For example, using a PIC to generate sine/square/sawtooth wave samples, having one or more cascading analogue or digital filters and capturing input using an audio input socket. This set up could show how cascading filters behave on a signal in a practical setting, and help readers to learn from experiment. For some of us, it is very hard to apply these ideas though theory without having seen/understood the impact of them in a real circuit application.

Another idea for a series is to explain how (at low level) three-phase mains supplies are kept in phase on the power grid (avoiding short circuits when connecting generators) and as an extension, how a home generator (eg wind turbine) can supply power back into the grid. It would be good to cover voltage, current, power, phase, synchronisation and circuits. As well as being technically interesting, this would be very useful for 'green' applications. Plus, is it possible to demonstrate in a practical way the effect on phase of inductive and capacitive loads?

I also like your current ladder logic *Teach-In 2010* series. Process electronics are interesting and I think you have made this accessible to both new and more experienced readers.

In a more advanced area, is their any chance of getting an *EPE* deal on FPGA demo boards? It would make a nice fast USB-connected data acquisition board. I do think you should concentrate on PICs, but it would be nice to learn a bit about FPGAs.

Last, I have a quick practical question. I have several 25V, 250-300mA loads, all with a common ground. What would be the best component to provide a 'high side' drive from a PIC with the minimum number of components (resistors, semiconductors) without using relays?

I hope you found these points interesting and that you can provide some feedback.

Keep up your good work

Robert Green, via email

Positive reader feedback is always welcome! We will certainly take a look at some of your article suggestions, although at present we have no plans to do a deal on FPGA demo boards. We'd be grateful to hear from any readers with elegant solutions to Robert's interface/drive question but do see this month's Circuit

IF YOU HAVE A SUBJECT YOU WISH TO DISCUSS ON THIS PAGE PLEASE EMAIL US AT:

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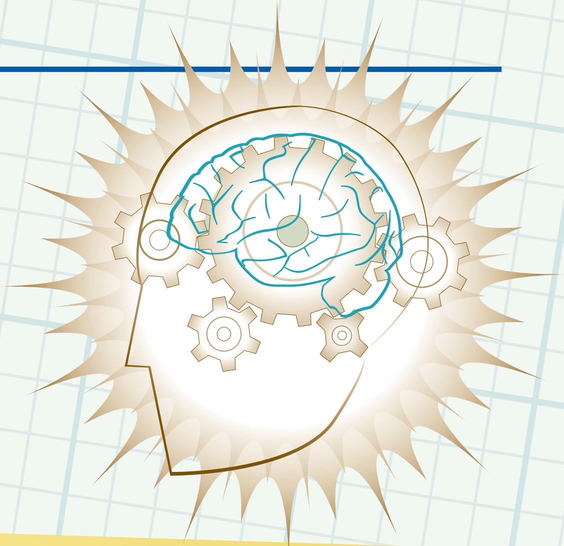
Ingenuity Unlimited

Our regular round-up of readers' own circuits



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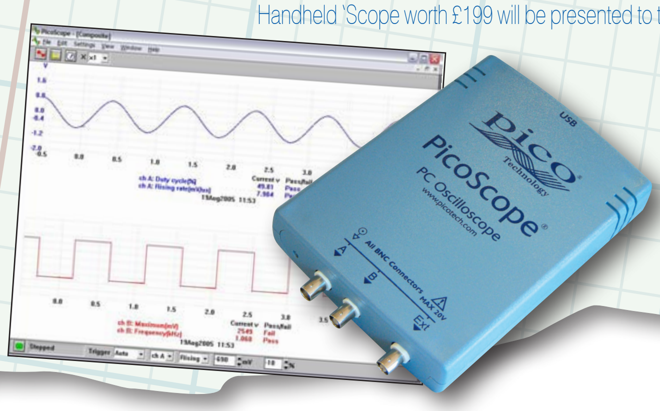

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The circuits shown have NOT been proven by us. **Ingenuity Unlimited** is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: Ingenuity Unlimited, Wimborne Publishing Ltd., Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU. Email: editorial@epemag.wimborne.co.uk.

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Wartbox – *Power spot*

EVERYONE has at least one redundant plug-in power adaptor or 'wall-wart' as the Americans sometimes call them. The 'wartbox' offered here converts a wall-wart into a useful (and small) variable PSU. It takes up very little space on the bench and gives enough power for experimenting with small circuits, component testing and battery charging.

Circuit details

This basic emitter-follower circuit used to be known as an 'amplified rheostat' and it's about as simple as you can get. My version, shown in Fig.1, supplies up to 8V/100mA through a pair of lever-type loudspeaker terminals. The circuit diagram shows the components I used, but there's no need to copy this exactly, use whatever suitable parts you have available. I built mine entirely out of 'recycled' parts in a small plastic box (7cm × 5cm).

Here are some hints: Capacitor C1 should be the highest value you can get in the box, to improve voltage regulation. Wall-warts tend to be rather light on capacitance, so bigger is better.

Transistor TR2 can be anything capable of handling a watt or so of power. My heatsink was a lump of aluminium, about 4cm × 5cm, entirely inside the box and it only gets warm at maximum load.

The ratings printed on wall-warts (plug-in mains adaptors) seem to be fairly meaningless. It's best to measure the off-load voltage (*V*) and the short-circuit current (*I*) for yourself. The maximum power available is around IV/4 watts, so your heatsink needs to handle this.

Use a reasonably new wall-wart built to modern standards. Steer clear of the high-powered ones unless you are an experienced constructor.

Safety

Safety comes from the current-limiting and mains-isolation provided by the wall-wart. Check that a brief short-circuit doesn't make it too hot, and that there is an infinite resistance between the mains pins and the output connector. **Wall-warts don't provide a ground connection, so you will have to provide this yourself if needed.**

Note that you should only construct this circuit if you are suitably qualified – mains electricity can kill!

Walter Gray, Farnborough

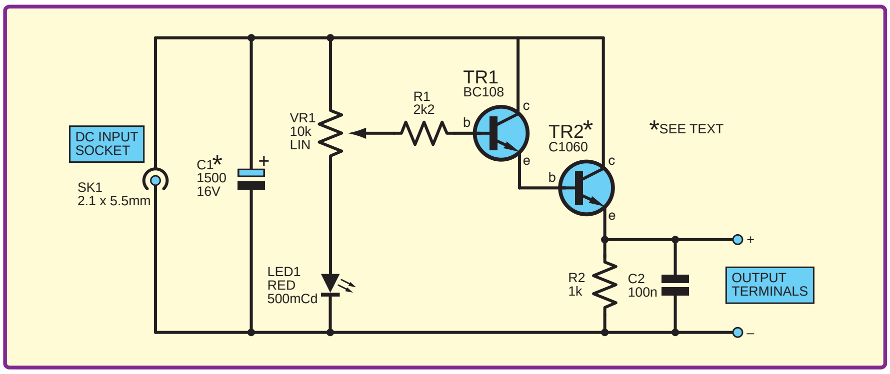


Fig.1. Circuit diagram for the Wartbox variable PSU

Auto TV/AV1 Selector – *Standby to go!*

IF YOU'RE using a set-top box (STB) or personal video recorder (PVR) to watch digital TV via Freeview, cable or satellite, like me you might have tired of having to select the AV1 input each time you switch on the TV or take it out of standby (the default source being its integral analogue tuner).

I'm sticking with my Panasonic TX-W28R4 TV, which uses the very common Euro 4 chassis, for a while yet as – among other things – the upscaling needed in flat-screen displays for standard definition pictures is still problematic and CRTs remain the gold standard for 'real' pictures (rather than the cartoons usually on display in the showrooms). If you have a Panasonic TV, the label on the rear will tell you if it uses the Euro 4 chassis.

It was easy to find a Euro 4 service manual on-line (for free) and a check of the M board showed that the TV's front panel 'TV/AV' switch grounds a line called 'keyscan' via a 2k2 resistor – see Fig.1. The resistor forms part of a chain which can be grounded at various points to effect different functions – a common technique, which simplifies the connection between the board containing the customer controls and the one where the system controller can be found.

A transistor can be used to simulate the action of the physical switch, but the timing of its operation is important: a delay of several seconds after switch-on is required or the command will be ignored.

Circuit

The circuit (Fig.2.) is based around a 74LS221 dual monostable IC, one half providing the initial delay, the other a pulse to simulate the button press. The TV board M has a main 5V supply and a standby 5V supply (for the remote control receiver and indicator); it's the former we need, as a rising edge derived from it is used to trigger the first monostable (IC1a), once the supply is established.

Capacitor C4 provides decoupling – during testing the circuit was on a long lead dangling from the TV, so a 100nF ceramic capacitor might suffice once mounted on the M board, close to other decoupling components. Components C1/R1 provide the initiating rising edge, C2/R2 a delay of 15s (0.7 × C × R) after which the falling edge of monostable IC1a's output triggers monostable IC1b to produce a 700ms pulse (C3/R3), which switches on transistor TR1 momentarily to select the AV1 input.

Steve Burgess, Woking, Surrey

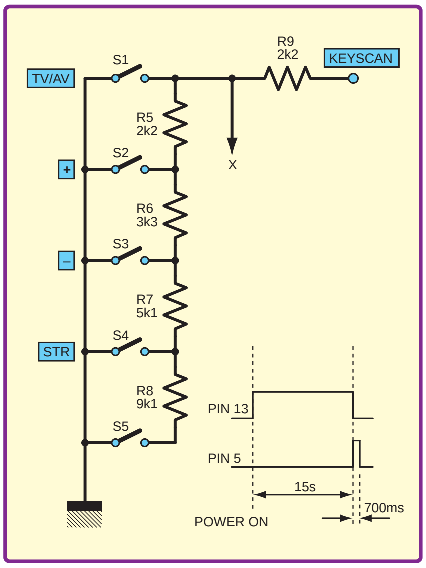


Fig.1. The TV/AV switch 'grounds' a line called 'keyscan' via a resistor

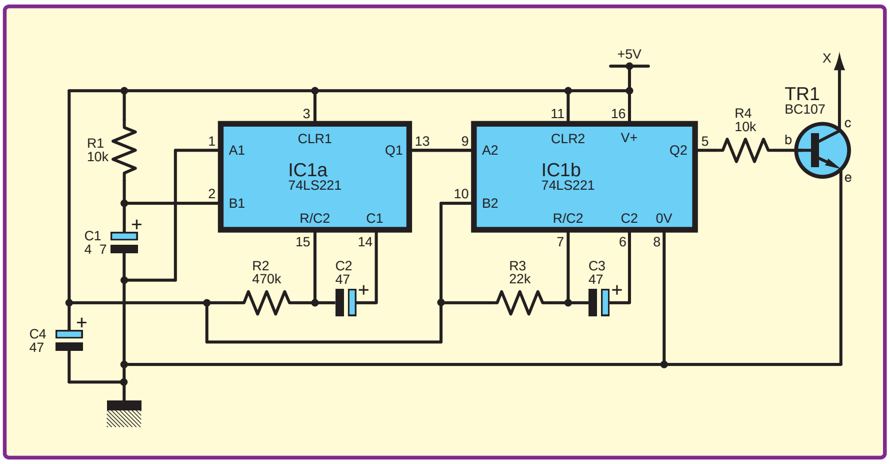
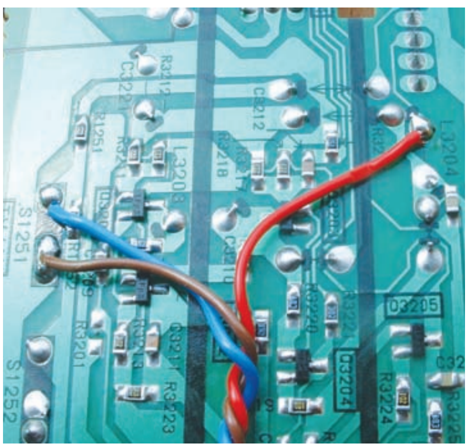


Fig.2. Circuit diagram for the Auto TV/AV1 Selector. Note point 'X' connects to point 'X' in Fig.1



INPUTS			OUTPUTS	
CLEAR	A	B	Q	$\bar{Q}$
L	X	X	L	L
X	H	X	X	X
X	X	L	X	X
H	L	↑	⊓	⊔
H	↓	H	⊓	⊔
↑	L	H	⊓	⊔

Fig.3. Function table for each monostable

Net Work

Alan Winstanley

Private, Keep Out!

This month, our Internet column turns its attention to the implications of protecting one's online privacy. When you surf the net or make a phone call, you leave behind some digital fingerprints as evidence of your activities. But has the state got any right to garner that data in pursuit of its own security agenda?

It seems that almost every month Britain sees another legal development that impinges upon our personal liberty. *EPE* readers throughout the EU might be uncomfortable to realise that details of pretty much every phone call (whether mobile or landline), fax, email, VOIP call and website visit that we make are to be recorded and made accessible by government and hundreds of agencies.

When I studied English law in the 1970s, I learned that a Statutory Instrument (SI) was a simple regulation made by (unelected) government officials to introduce routine petty bureaucracy. They were not debated by parliament and so the electorate had little say in them. An SI might cover simple road closure orders or implement lesser legal frameworks.

Today, this is only partly true, and we have arguably even less influence due to the overarching reach of European law. Already 3,000 statutory regulations have been made in 2009 (see the Office of Public Sector Information website at **http://www.opsi.gov.uk/si/si-2009-index**). Earlier this year, Statutory Instrument No. 859 slipped silently into port in the form of the Data Retention (EC Directive) Regulations 2009. It compels public communications providers to store data related to our online and phone activities for at least 12 months. The deceptively simple SI can be read online at **http://tinyurl.com/cs75f6**.

Supposedly, implemented in the interests of fighting crime and terrorism, the law covers private individuals and small business data too. As far as our privacy is concerned, everything except the actual contents of our calls or email is recorded: when we log in, our IP address, the datestamp, the location of terminal equipment (which includes a mobile phone), geographical data and even the direction of our travel are recorded (mobile users take note). VOIP internet sessions (such as Skype) are captured the same way. 'Unsuccessful' communications (failed calls) are apparently not stored, but you can bet they will be available anyway: my ISP can already tell me how many times my ADSL line dropped and reconnected over the past month.

Even our car journeys are recorded, though you may not notice roadside ANPR (automatic number plate recognition) cameras scanning your number plate as you pass by. Many of the ramifications of this privacy law are beyond the scope of this column, but I believe it is important that readers bear in mind that some UK authorities have already abused the scope of these monitoring laws. They have a poor record of losing it altogether or taking other liberties with our data.

Personal viewpoints about the pros and cons of data retention vary, but I do not subscribe to the principle that innocent people should have nothing to fear about their data being captured and retained for lengthy periods in this way. The recording of our data might well suit the police, but I know I will not break the law, so I don't need my data retaining as a deterrent, as though I am only 'innocent-ish'.

Nor is this monitoring a new British or EU phenomenon: the ultra low-profile Echelon data interception system stores data passing between the UK, USA, Canada, Australia and New Zealand. Historically, Echelon relates to preventing industrial espionage and intercepting satellite data, and is said to be capable of analysing the contents of calls (eg perhaps scanning a phone call or email for the word 'bomb'). An interesting summary is available at **http://en.wikipedia.org/wiki/Echelon_(signals_intelligence)**.

Dynamite data

Some other aspects of personal privacy are worth remembering. Whenever you visit a web site, you leave a breadcrumb trail of tell-tale footprints. Your IP address is recorded somewhere, and by using the timestamp and IP address, it is possible to reverse-lookup the traffic and backtrack it to your dial-up or ADSL – enabled phone line in any country. From there your identity and location can be determined.

By using a proxy service, you introduce a third-party buffer which intercepts Internet traffic on your behalf under its own IP address. One subscription-based service is **Anonymizer.com**. A user-friendly way of checking your IP address is with **www.ipchicken.com** and you can see how your genuine IP address is altered by Anonymizer.com, as seen by the rest of the world. Of course, we can never know what data is kept by this proxy service: whether any back doors are available for the FBI to use is unconfirmed, but personally I cannot believe that law enforcement agencies could not access our data if 'push came to shove'.

Not to overlook the data stored on your PC either, notably in the cache where temporary internet files and cookies are stored. A contact in the Serious Fraud Office confirms they have a whole department dedicated to using forensics software to recover 'deleted' or hidden data from dodgy disks, memory cards, Windows registries, RAM chips and mobile phones.

Numerous consumer-level data privacy packages are available to delete PC data, Cyberscrub (**www.cyberscrub.com**) being one used by the author to repel boarders, but there is little data that cannot be reverse-engineered with forensics software such as EnCase by Guidance Software (**www.guidancesoftware.com**), as used by all the leading police authorities. The only sure way to destroy data is probably to dynamite it: and even then they will capture your DNA from the shrapnel. Britain has the world's largest DNA database, which is doubtless a source of pride for some agencies. It's also enough to make anybody completely paranoid.

My online monthly column at **www.epemag.com** has more interesting snippets, including a topical *Space Watch* feature. You can email me at **alan@epemag.demon.co.uk**

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Mike Tooley

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RADIO

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I. D. Poole

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Topics covered include: The equipment that is needed; Setting up the shack; Which aerials to use; Methods of construction; Preparing for the licence.

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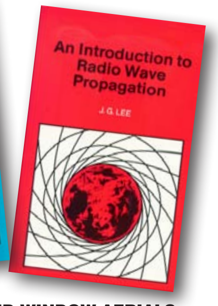

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Radio wave propogation is one of the more important discoveries made in the early 20th century. Although technology lagged behind early experimenters pursued this newly discovered phenomenon eagerly for, in understanding the physics of propagation, they were discovering more about our Universe and its workings.

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THEORY AND REFERENCE

BEBOP TO THE BOOLEAN BOOGIE
Second Edition
Clive (call me Max) Maxfield

This book gives the "big picture" of digital electronics. This in-depth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

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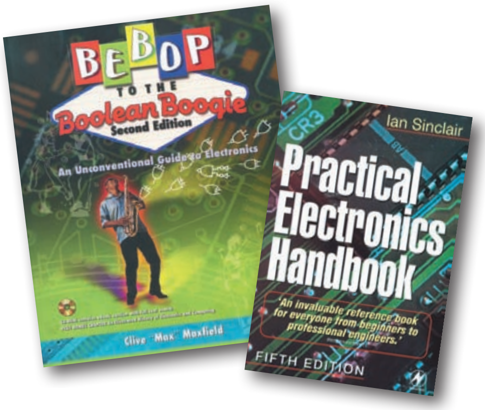

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Martin Bates

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Step-by-step examples in assembly language are used to illustrate a comprehensive set of interfaces, and these can be run interactively on circuit simulation software, used to aid understanding without the need to build real hardware.

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R. A. Penfold

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In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

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Ian R. Sinclair

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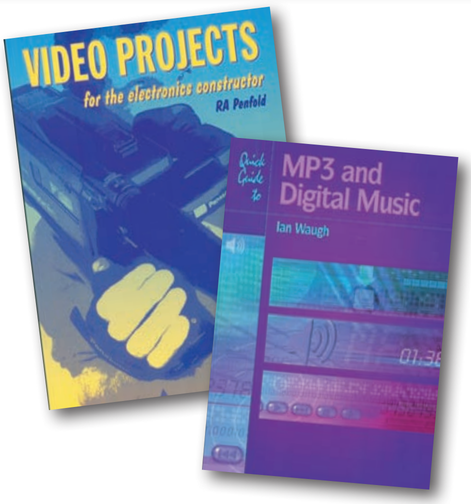

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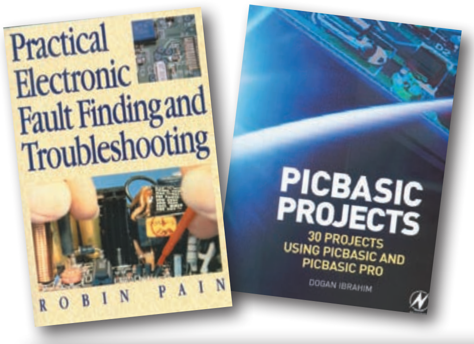

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FEBRUARY '10 ISSUE ON SALE 14 JANUARY

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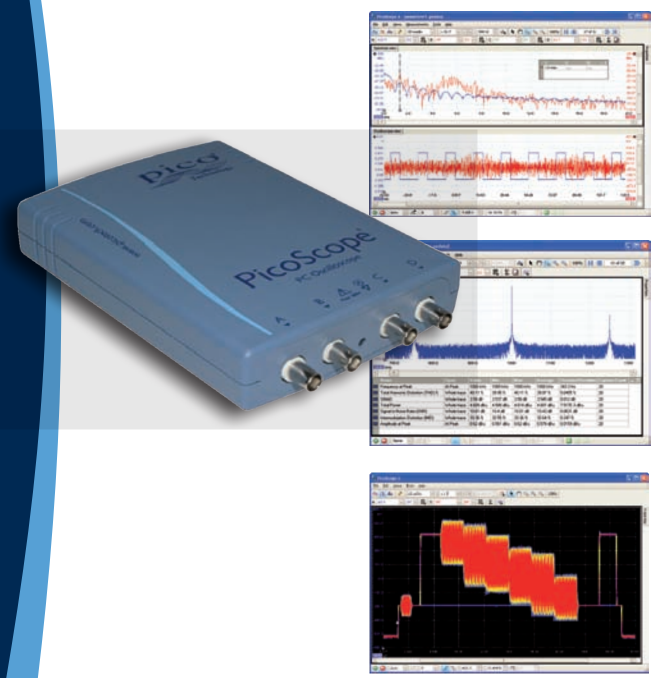

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